Resource Characterization and Quantification of Natural Gas-Hydrate and Associated Free-Gas Accumulations in the Prudhoe Bay – Kuparuk River Area on the North Slope of Alaska

December 2006 Quarterly Technical Report
Seventeenth Technical Quarterly Report: October 2006 – December 2006
Cooperative Agreement Award Number DE-FC-01NT41332

Submitted to the
United States Department of Energy
National Energy Technology Laboratory
ADD Document Control

by
BP Exploration (Alaska), Inc.
Robert Hunter (Principal Investigator)
P.O. Box 196612
Anchorage, Alaska 99519-6612
Email: hunterrb@bp.com
robert.hunter@asrcenergy.com
Tel: (907)-339-6377

in collaboration with
United States Geological Survey
Tim Collett (Principal Investigator)
Denver Federal Center
Box 25046, MS939
Denver, CO 80225

February 27, 2007

DISCLAIMER

ABSTRACT

Methane hydrate may contain significant offshore and onshore arctic gas resources. The appraisal phases of this study are designed to help determine whether or not gas hydrate can become a technically and economically recoverable gas resource. The Phase 1-2 reservoir characterization, development scenario modeling, and associated studies indicated that 0-12 TCF gas may be technically recoverable from 33 TCF gas-in-place (GIP) Eileen trend gas hydrate beneath industry infrastructure within the Milne Point Unit (MPU), Prudhoe Bay Unit (PBU), and Kuparuk River Unit (KRU) areas on the Alaska North Slope (ANS). Modeled production methods involve subsurface depressurization and/or thermal stimulation of pore-filling gas hydrate into gas and water components.

Phase 2 studies included rate forecasts and hypothetical well scheduling, methods typically employed to evaluate the development potential of conventional large gas accumulations. This work helped quantify: 1. Potential to technically produce gas from the 33 TCF GIP Eileen trend gas hydrate resource using conventional petroleum technologies and 2. Range of 0-12 TCF possible recoverable resource based on potential future development schemes. Phase 2 studies culminated in recommendations to acquire Phase 3a stratigraphic test static data including 400-600 feet core, extensive wireline logs, and MDT wireline tests within the Mt Elbert intra-hydrate MPU prospect interpreted from the Milne 3D seismic survey. Phase 3b studies, if approved, would acquire additional static data and include production testing, likely from a gravel pad within production infrastructure.

Phase 2 production forecast and regional schematic modeling studies included downside, reference, and upside cases. Reference case forecasts with type-well depressurization-induced production rates of 0.4-2.0 MMSCF/D predict that 2.5 TCF of gas might be produced in 20 years, with 10 TCF ultimate recovery after 100 years; it is important to note that typical industry forecasts would not exceed 50 years. Downside cases envision research pilot failure and economic or technical infeasibility. Upside cases identify additional potential if Phase 3 data acquisition would confirm upside modeling results of pressure-induced, thermally enhanced, or chemically stimulated gas hydrate dissociation into movable gas. Phase 3a field studies will be conducted in early 2007 to acquire data to help mitigate uncertainty in potential gas hydrate productivity. A Phase 3a stratigraphic test is planned, permitted, and scheduled to drill by February 2007. A Phase 3b production test is not currently approved by DOE or BP.

ACKNOWLEDGEMENTS

This cooperative DOE-BPXA research project has helped facilitate industry interest in the resource potential of shallow natural gas hydrate accumulations. This research could help determine whether or not methane hydrate may become an additional unconventional gas resource and DOE and BPXA support of these studies is gratefully acknowledged.

Efforts of DOE National Energy Technology Lab staff Brad Tomer, Ray Boswell, Rick Baker, Tom Mroz, Kelly Rose, Eilis Rosenbaum, and others have enabled continuation of this and associated research projects. Scott Digert and others at BPXA continue to promote the importance of this cooperative research within industry. BPXA staff support and planning efforts of Micaela Weeks, Larry Vendl, Dennis Urban, and others leading to well operations and data acquisition is crucial to designing Phase 3a for success. The State of Alaska Department of Natural Resources through the efforts and leadership of Dr. Mark Myers, Bob Swenson, Paul Decker, and others has consistently recognized the contribution of this research toward identifying a possible additional unconventional gas resource and actively supported the Methane Hydrate Act of 2005 to enable continued funding of these studies.

The USGS has led ANS gas hydrate research for nearly 3 decades. Dr. Tim Collett continues to promote the importance of this area to gas hydrate research and potential future development. Seismic studies accomplished by Tanya Inks at Interpretation Services and by USGS scientists Tim Collett, Myung Lee, Warren Agena, and David Taylor identified multiple MPU gas hydrate prospects. Support by USGS staff Bill Winters, Bill Waite, and Tom Lorenson and Oregon State University staff Marta Torres and Rick Colwell is gratefully acknowledged. Steve Hancock at APA (RPS Energy) and Peter Weinheber at Schlumberger have helped design the Phase 3a wireline testing program. Scott Wilson at Ryder Scott has progressed reservoir models from initial studies by the University of Calgary (Dr. Pooladi-Darvish) and the University of Alaska Fairbanks (UAF). The Canadian Modeling Group (CMG) STARS program was adapted to an industry-standard production model of gas hydrate-bearing reservoir behavior and has helped assess the regional development potential of Alaska North Slope gas hydrate (if proven as a resource). Dr. Shirish Patil and Dr. Abhijit Dandekar have helped redevelop the UAF School of Mining and Engineering into an arctic regions gas hydrate research center. The University of Arizona reservoir characterization studies led by Dr. Bob Casavant with Dr. Karl Glass, Ken Mallon, Dr. Roy Johnson, and Dr. Mary Poulton have described the structural and stratigraphic architecture of the ANS Sagavanirktok formation gas hydrate-bearing reservoir sands.

Current related studies of gas hydrate resource potential are too numerous to mention here. National Labs studies include Dr. Pete McGrail, CO_2 Injection, and Dr. Mark White, reservoir modeling, at Pacific Northwest National Lab and Dr. George Moridis, reservoir modeling, at Lawrence Berkeley National Lab. The Colorado School of Mines under the leadership of Dr. Dendy Sloan continue to progress laboratory and associated studies of gas hydrate. The significant efforts of international gas hydrate research projects such as those supported by the Directorate General of Hydrocarbons by the government of India and by the Japan Oil, Gas, and Metals National Corporation (JOGMEC) with the government of Japan are contributing significantly to a better understanding of the resource potential of natural methane hydrate. JOGMEC and the government of Canada support of the 2002 and current Mallik project gas hydrate studies in Northwest Territories, Canada are gratefully acknowledged. This cooperative DOE-BPXA research project builds upon the accomplishments of many prior government, academic, and industry studies.

TABLE OF CONTENTS

1.0 LIST OF TABLES AND FIGURES

2.0 INTRODUCTION

The cooperative research between BP Exploration (Alaska), Inc. (BPXA) and the U.S. Department of Energy (DOE) is helping to characterize and assess Alaska North Slope (ANS) methane hydrate resource and is helping to identify technical and commercial factors that could enable government and industry to understand the future development potential of this possible unconventional energy resource. Results of Phase 1-2 reservoir characterization, reservoir modeling, regional schematic modeling, and associated studies culminated in approval to proceed into a 2007 Phase 3a stratigraphic test to acquire data designed to help mitigate potential recoverable resource uncertainty. Future Phase 3b production testing is a key goal of the Federal Research and Development program and may follow, but this remains to be evaluated. Collaborative research partners include U.S. Geological Survey (USGS), Arctic Slope Regional Corporation Energy Services, Ryder Scott Company, APA Engineering, University of Arizona, University of Alaska Fairbanks, Pacific Northwest National Lab, Lawrence Berkeley National Lab, and others.

Methane hydrate may contain a significant portion of world gas resources within offshore and onshore arctic regions petroleum systems. In the United States, accumulations of gas hydrate occur within pressure-temperature stability regions in both offshore and also onshore near-permafrost regions. USGS probabilistic estimates indicate that clathrate hydrate may contain a mean of 590 TCF in-place ANS gas resources (Figure 1). Over 33 TCF in-place potential gas hydrate resources are interpreted within shallow sand reservoirs beneath ANS production infrastructure within the Eileen trend (Figure 2). Gas hydrate accumulations require the presence of all petroleum system components (source, migration, trap, seal, charge, and reservoir). Future exploitation of gas hydrate would require developing feasible, safe, and environmentally-benign production technology, initially within areas of industry infrastructure. In the United States, the ANS onshore and Gulf of Mexico (GOM) offshore are currently known to favorably combine these factors. The information and technology being developed in this onshore ANS program will be an important component to assessing the possible productivity of the potentially much larger marine hydrate resource. The resource potential of gas hydrate remains unproven, but if proven, could increase ANS gas resources and could lead to greater U.S. energy independence.

In 1972, the existence of natural methane hydrate within ANS shallow sand reservoirs was confirmed by data acquired in the Northwest Eileen State-02 well. Although up to 100 TCF in-place gas may be trapped within the gas hydrate-bearing formations beneath existing ANS infrastructure, it has been primarily known as a shallow gas drilling hazard to the hundreds of well penetrations targeting deeper oil-bearing formations and has drawn little resource attention due to no ANS gas export infrastructure and unknown potential productivity. Characterization of ANS gas hydrate-bearing reservoirs and improved modeling of potential gas hydrate dissociation processes led to increasing interest to study gas hydrate resource and production feasibility.

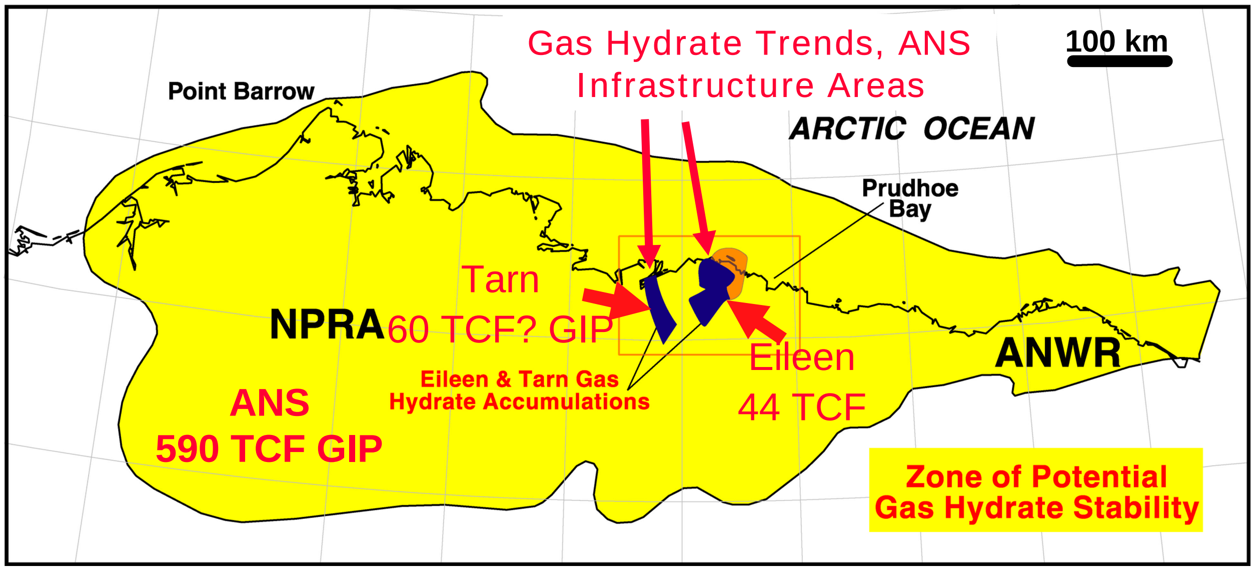


Figure 1: ANS Gas Hydrate Stability Zone Extent. The USGS has estimated 590 TCF methane in place in hydrate form in this region (Courtesy USGS).

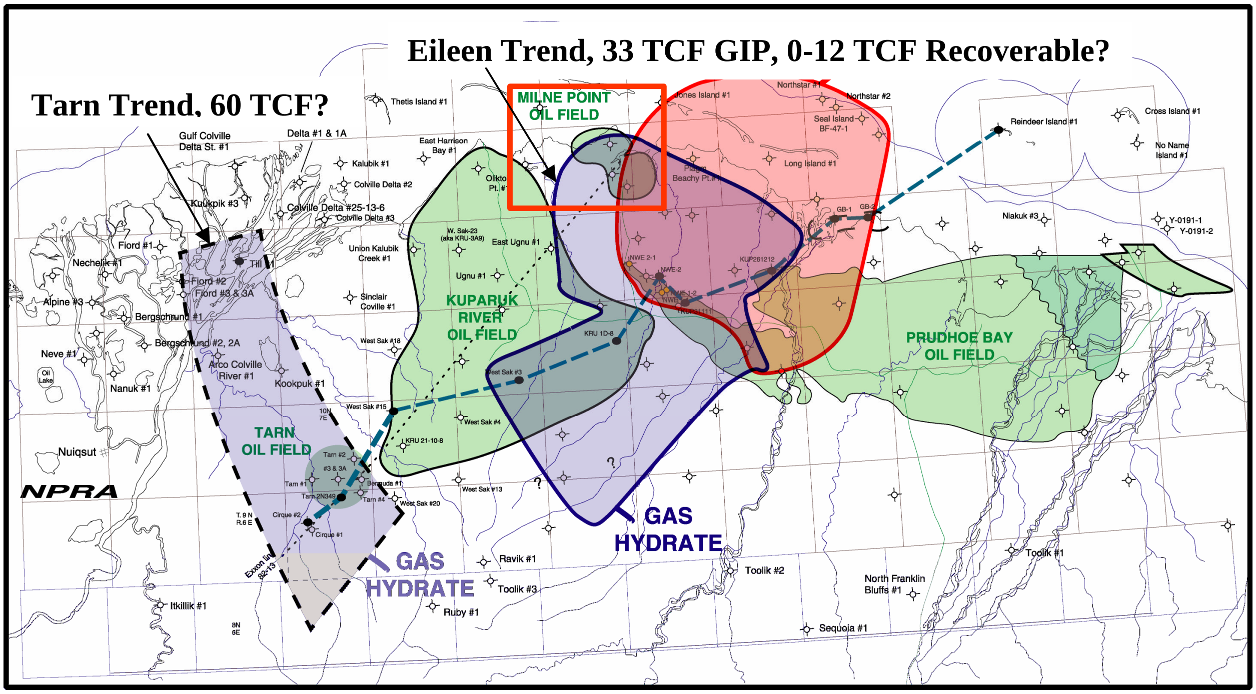


Figure 2: Eileen and Tarn Gas Hydrate Trends and ANS Field Infrastructure (modified after Collett, 1998).

If gas can be technically produced from gas hydrate and if studies help prove production capability at economically viable rates, then methane dissociated from ANS gas hydrate could help supplement fuel-gas, provide additional lean-gas for reservoir energy pressure support, sustain long-term production of portions of the geographically-coincident 20-25 billion barrels viscous oil resource, and/or potentially supplement conventional export-gas in the longer term.

As part of a multi-year effort to encourage these feasibility studies, the DOE also supports significant laboratory and numerical modeling efforts focused on the small scale behaviors of gas hydrate. Concurrently, the USGS has assessed the potential in-place resource potential and participated in field operations with DOE and others to acquire data within many naturally occurring gas hydrate accumulations throughout the world. There remain significant challenges in quantifying the fraction of these in-place resources that might eventually become a technically-feasible or possibly a commercial natural gas reserve. This study estimates this potential ANS prize within the Eileen trend and recommends additional research, data acquisition, and field operations.

A “chicken and egg” problem has hindered unproven resource research and development in the past; an “unconventional” resource commonly requires a few positive examples before it can generate stand-alone interest from industry. This was true for tight gas resources in the 1950-1960’s, Coal-Bed-Methane plays in the 1970-1980’s and the shale gas resources in the 1990-2000’s. In each case, the resource was thought to be technically infeasible and uneconomic until the combination of market, technology (new or newly applied), and positive field experience helped motivate widespread adoption of unconventional recovery techniques in an effort to prove whether or not the resource could be technically and commercially produced. In an attempt to bridge this gap, Phase 2 gas hydrate reservoir modeling efforts were coupled with a series of possible regional schematic models to quantify a suite of potential recoverable reserve outcomes.

These regional schematic modeling scenarios indicated that 0-12 TCF gas may be technically recoverable from 33 TCF in-place Eileen trend gas hydrate beneath ANS industry infrastructure within the Milne Point Unit (MPU), Prudhoe Bay Unit (PBU), and Kuparuk River Unit (KRU) areas. Production forecast and regional schematic modeling studies included downside, reference, and upside cases. Reference case forecasts with type-well depressurization-induced production rates of 0.4-2.0 MMSCF/D predict that 2.5 TCF of gas might be produced in 20 years, with 10 TCF ultimate recovery after 100 years (typical industry forecasts would not exceed 50 years). The downside case envisions research pilot failure and economic or technical infeasibility. Upside cases identify additional potential recoverable resource. Additional static data acquisition and possible future production testing could help validate whether or not these upside model results might occur in a future potential development using pressure-induced, thermally enhanced, and/or chemically stimulated dissociation of gas hydrate into movable gas. Modeled production methods involve subsurface depressurization and/or thermal stimulation of pore-filling gas hydrate into gas and water components. Phase 2 studies included rate forecasts and hypothetical well scheduling, methods typically employed to evaluate potential conventional large gas development projects. This work helped quantify: 1. Potential to technically produce gas from the 33 TCF GIP Eileen trend gas hydrate resource using conventional petroleum technologies and 2. Range of 0-12 TCF possible recoverable resource based on potential future development schemes. Phase 2 studies culminated in recommendations to acquire Phase 3a stratigraphic test static data including 400-600 feet core, extensive wireline logs, and MDT wireline tests within the Mt Elbert intra-hydrate MPU prospect interpreted from the Milne 3D seismic survey. Phase 3a field studies were approved to acquire data to help mitigate uncertainty in potential gas hydrate productivity. The Phase 3a stratigraphic test is planned, permitted, and scheduled to drill by February 2007. Phase 3b studies, if approved, would acquire additional static data and include production testing, likely from a gravel pad within production infrastructure. A Phase 3b production test is not currently approved by DOE or BP.

2.1 Project Open Items

Phase 3a Stratigraphic Test definitization documents were approved in late 2006. Contract amendments were completed in December 2006 to better define operations liabilities and extend Phase 3a studies through end-December 2007.

2.2 Project Status Assessment and Forecast

Project technical accomplishments from October 2006 through end-December 2006 are presented by associated project task. The attached milestone form (Appendix A) presents project task duration and completion timelines.

2.3 Project Research Collaborations

Project objectives significantly benefit from DOE awareness, support, and/or funding of the following associated collaborations, projects, and proposals.

1. **Reservoir Model studies:** DOE NETL coordination of reservoir modeling significantly increased collaborative reservoir modeling efforts with Japan, Lawrence Berkeley National Lab (LBNL), and Pacific Northwest National Lab (PNNL). This important work should continue into simulation of field-scale gas hydrate bearing reservoirs. The studies to-date have facilitated a common understanding of how these different gas hydrate reservoir models handle the basic physics of gas hydrate dissociation processes within gas hydrate-bearing formations. Contributors to this effort include: Masanori Kurihara (Japan Oil Engineering Co., Ltd.), Yoshihiro Masuda (The University of Tokyo), Pete McGrail (Pacific Northwest National Laboratory), George Moridis (Lawrence Berkeley National Laboratory, University of California), Hideo Narita (National Institute of Advanced Industrial Science and Technology), Mark White (Pacific Northwest National Laboratory), Joseph W. Wilder (formerly National Energy Technology Laboratory, U.S. Department of Energy), Scott Wilson (Ryder Scott Company, Consultant to BP-DOE project), Timothy Collett (U.S. Geological Survey), and Robert Hunter (ASRC Energy Services; BP Exploration (Alaska), Inc.).
2. **DE-FC26-01NT41248:** UAF/PNNL/BPXA studies to investigate the effectiveness of CO_2 as a potential enhanced recovery mechanism for gas dissociation from methane hydrate. DOE currently supports this associated project research which may help facilitate a future field test of this technology. If Phase 3b production testing proceeds, an Alaskan source of CO_2 for latter stage testing may be available.
3. **UAF/Argonne National Lab project:** This associated project was approved for funding by the Arctic Energy and Technology Development Lab (AETDL), forwarded to NETL for review, and was funded in mid-2004. The project is designed to determine the efficacy of Ceramicrete cold temperature cement for possible future gas hydrate drilling

and completion operations. Evaluating the stability and use of an alternative cold temperature cement may enhance the ability to maintain the low temperatures of the gas hydrate stability field during drilling and completion operations and help ensure safer and more cost-effective operations. In early 2006, the Ceramicrete material was approved for field testing at the BJ Services yard in Texas (primary contact Lee Dillenbeck). Although Ceramicrete was not yet field tested in time to be evaluated for use in 2006-2007 Alaska operations, successful future yard testing of the material may enable limited testing in Alaska project operations. We remain in communication with ANL and BJ Services.

4. **Precision Combustion, Inc. (PCI) – DOE collaborative research project:** Potential synergies from this DOE-supported research project with the BPXA – DOE gas hydrate research program were recognized in December 2003 by Edie Allison (DOE). Communications with Precision Combustion researchers indicate possible synergies, particularly regarding potential in-situ reservoir heating. Successful modeling and lab work could potentially proceed into field applications in either viscous oil or future gas hydrate operations. BPXA provided a letter in April 2004 in support of progression of PCI's project into their phase 2: prototype tool design and possible surface testing. If the project proceeds into Phase 3b operations, a thermal component of production testing may be necessary and a delivery mechanism may incorporate this technology.
5. **UAF shallow resource (gas hydrate and viscous oil) research initiatives:** UAF proposed that AETDL fund Alaska shallow resource research initiatives. This associated research could provide benefits to this project. It should be noted that industry could take a leadership role in these initiatives, similar to the approach taken in this project.
6. **Japan gas hydrate research:** Progress toward completing the objectives of this project remain aligned with gas hydrate research by Japan Oil, Gas, and Metals National Corporation (JOGMEC), formerly Japan National Oil Corporation (JNOC). JOGMEC remains interested in research collaboration, particularly if this project proceeds into production testing operations. Communications with JOGMEC were limited during the reporting period, but were renewed in June 2006, to inform JOGMEC that the BP-DOE project is proceeding into Phase 3a stratigraphic test field operations. JOGMEC may proceed into future (2007-2008?) production test operations at the Mallik field site.
7. **India gas hydrate research:** India's Institute of Oil and Gas Production Technology (IOGPT) indicates a continued interest in participating with the BPXA – DOE research program in correspondence/discussion with DOE. Dr. Tim Collett, partner in the BPXA-DOE research team, and Ray Boswell, DOE gas hydrate program, led and participated in, respectively, certain aspects of the data acquisition at multiple offshore India field sites. India plans to send a technical observer to view ANS Phase 3a operations and data acquisition. The value of international research collaboration is recognized.
8. **Korea gas hydrate research:** Korea may be developing a gas hydrate research program. Korea has discussed potential participation in future Alaska gas hydrate research with USGS. BPXA has not initiated contact with Korea.
9. **U.S. Department of Interior, USGS, BLM, State of Alaska DGGS:** An additional collaborative research project under the Department of Interior (DOI) may provide significant benefits to this project. The BLM, USGS, and the State of Alaska recognize that gas hydrate is potentially a large untapped ANS onshore energy resource. To develop a more complete regional understanding of this potential energy resource, the BLM, USGS and State of Alaska Division of Geological and Geophysical Surveys

(DGGS) have entered into an Assistance Agreement to assess regional gas hydrate energy resource potential in northern Alaska. This agreement combines the resource assessment responsibilities of the USGS and the DGGS with the surface management and permitting responsibilities of the BLM. Information generated from this agreement will help guide these agencies to promote responsible development if this potential arctic energy resource becomes proven. The DOI project is working with the BPXA – DOE project to assess the regional recoverable resource potential of onshore natural gas hydrate and associated free-gas accumulations in northern Alaska, initially within current industry infrastructure.

2.4 Project Performance Variance

Detailed project performance variance is noted by quarter in the Project Status Reports on standard forms 4600.

3.0 EXECUTIVE SUMMARY

This Quarterly report encompasses project work from October 1, 2006 through end-December 2006. Research accomplished during this reporting period included detailed planning of coring, wireline logging, and wireline testing operations in preparation for Phase 3a stratigraphic test well operations. Project accomplishments during the reporting period included:

- Updated project budget and contracts for Phase 3a; modified scope-of-work as-needed
    - Finalized Phase 3a stratigraphic test well operations and data acquisition
    - Input updates to Amendments 15-16 and updated subcontracts
        - Added Phase 3a operations and data analyses contracts with DrillCool, OMNI Lab, Corion (Reed-Hycalog), Oregon State University
    - Developed, reviewed, and approved Phase 3a definitization and budget documents
    - Prepared Authority-for-Expenditure documents consistent with budget categories
    - Rationalized budget and updated drilling/data acquisition cost estimates
    - Established cost-cutting tiers to maintain project within budget
        - Implemented Tier 1 cut to TD well at 3000 feet (versus 4000 feet)
- Maintained project reports, electronic and hardcopy files, documentation, and backups
- Considered addition of short-term Drill-stem testing (DST) to data acquisition program
    - Worked with Schlumberger and Ryder Scott to develop viable DST plans
    - Reviewed DST from 1972 NWEileen-02 for insight to current plans
    - Evaluated DST plans with BP operations and wells group
    - Investigated and rejected non-rig well abandonment options
    - Arranged DST equipment options ($20K/day) contingency if program approved
    - Rejected DST option due to high ice-pad operations cost and abandonment concern regarding downhole Electrical Submersible Pump (ESP) cable/equipment
- Developed detailed core planning documentation in cooperation with experts from BP, Corion, and OMNI Lab (Appendix B)
- Led/attended multiple meetings regarding well operations and data acquisition plans
    - Forwarded safety, policy, training, and procedure documents to all subcontractors
    - Completed coring, logging, wireline testing risk analyses and plans
    - Switched to oil-based (vs. water-based) chilled mud for operations and safety
    - Prepared field staff roster, assignments, and shift schedules
    - Finalized plans and contracts, permits, and materials acquisition

  - Documented risks, addressed concerns, and developed plans to mitigate risks
  - Rechecked surface, ice pad/road, and well bottom hole locations
  - Provided action reviews and coordinated well operations plans
  - Finalized logging-during-drilling, wireline, and MDT program plans
  - Finalized mud program and incorporated DrillCool, Inc. mudchilling system
  - Finalized core program and procedures and evaluated and selected vendors
    - Finalized core acquisition parameters with Corion (ReedHycalog)
    - Finalized core handling and processing program with OMNI and others
    - Finalized onsite data acquisition and core handling procedures
- Presented well plans to MPU ANS operations staff; visited MtElbert-01 MPU wellsite
- Prepared/presented project status update for DOE Advisory Committee meetings
- Prepared/presented project summary and plans for Harts Energy Gas Hydrate Conference
- Met with BP Petroleum System and Geochemistry experts; discussed prospect details
- Considered Schlumberger perforating/completion studies for possible use in Phase 3b
  - Followup in November meeting at Rosharon lab facility with Ian Walton, others
  - Outlined potential for CO2-hydrate formation and perforation Phase 3a-b studies
- Implemented all materials acquisition for Phase 3a well operations

4.0 EXPERIMENTAL

During the reporting time period from October 2006 through end-December 2006, no experimental activities were performed.

4.1 TASK 5.0, Logging and Seismic Technology Advances

Prior quarterly reports and the June 30, 2005 topical report document seismic attribute study within the Milne 3D seismic data and the interpreted relation between seismic amplitude and gas hydrate-bearing zone thickness and saturation. The Mt Elbert-01 stratigraphic test well (Phase 3a) data acquisition wireline logging and coring program was designed to delineate this direct seismic detection of thickness and pore fluid saturation within these interpreted gas hydrate-bearing reservoirs. Seismic modeling and interpretation confirm that seismic velocity, amplitudes, and wavelet character may respond to fluid and reservoir changes within the gas hydrate-bearing reservoirs. Fourteen gas hydrate-bearing prospects containing an estimated 600 BCF gas-in-place have been interpreted from MPU seismic data within the northern portion of the Eileen gas hydrate trend. The Mt Elbert-01 stratigraphic test well is designed to delineate the Mt Elbert gas hydrate prospect, which may contain up to 90 BCF gas in-place.

4.2 TASK 6.0, Reservoir and Fluids Characterization

The University of Arizona (UA) remains under a no-cost extension pending evaluation of accomplished work and results of Phase 3a stratigraphic test. Meetings were held in early-December at UA; discussions included status of Sagavanirktok correlations and mapping.

4.3 TASK 7.0: Drilling, Completion, and Production Lab Studies

The University of Alaska Fairbanks (UAF) remains under a no-cost extension pending evaluation of accomplished work and results of Phase 3a stratigraphic test. The phase behavior, relative permeability, and formation damage experimental work may be extended to study core samples collected within the proposed Mt Elbert-01 stratigraphic test well.

5.0 RESULTS AND DISCUSSION

Project technical accomplishments from October 2006 through end-December 2006 are presented in chronological order by associated project task.

5.1 TASK 1.0: Research Management Plan

Task schedules are presented in attached milestones forms (Appendix A). Project expenditures are reported separately on financial forms 269A and 272. Per Amendment 15, future financial reports will be completed on form SF-269. Project status reports are reported separately on forms 4600.

- Submitted quarterly technical report 16 documenting July-end-September research update
- Submitted Status and Financial reports documenting July-end-September financial update
- Updated project contracts for Phase 3a and modified scope-of-work and budget
    - Input budget updates to Amendments 15-16 and updated subcontracts
    - Executed Amendments 12-16 following Phase 3a budget definitization approval
        - Added Phase 3a operations and data analyses contracts with DrillCool, OMNI Lab, Corion (Reed-Hycalog), Oregon State University
- Finalized Phase 3a stratigraphic test well operations, data and materials acquisition plans
    - Developed, reviewed, and approved Phase 3a definitization and budget documents
    - Prepared Authority-for-Expenditure documents consistent with budget categories
    - Rationalized budget and updated drilling/data acquisition cost estimates
    - Established cost-cutting tiers to maintain project within budget
        - Implemented Tier 1 cut to TD well at 3000 feet (versus 4000 feet)

5.2 TASK 2.0: Provide Technical Data and Expertise

- Maintained project electronic and hardcopy files, documentation, and backups
- Maintained awareness of Ugnu and Schrader Bluff core plans to help ensure MPU 2007 appraisal program synergies with gas hydrate core and MtElbert-01 well objectives

5.3 TASK 3.0: Wells of Opportunity, Data Acquisition

- Monitored BP drilling schedules and communicated with BP operations groups
    - Identified PBU L-pad vertical well candidate for 3-4Q07

5.4 TASK 4.0: Research Collaboration Link

- Reviewed, edited, wrote, and approved external publications and interviews as-needed
    - Reviewed gas hydrate literature and recent developments
    - Maintained and transferred knowledge of relevant other-project research
- AAPG abstract for April 2007 Regional Conference approved for oral presentation
- Prepared/presented project status update for DOE Advisory Committee meetings
- Prepared/presented project summary and plans for Harts Energy Gas Hydrate Conference
- Met with BP Petroleum System and Geochemistry experts; discussed prospect details
- Considered Schlumberger perforating/completion studies for possible use in Phase 3b
    - Followup in November meeting at Rosharon lab facility with Ian Walton, others
    - Outlined potential for CO2-hydrate formation and perforation Phase 3a-b studies

5.5 TASK 5.0: Logging and Seismic Technology Advances

United States Geological Survey
USGS Principle Investigator: Timothy Collett
USGS Participating Scientists: David Taylor, Warren Agena, Myung Lee, Tanya Inks (IS)

These studies significantly contributed to the selection of the MtElbert prospect for the Phase 3a stratigraphic test. The majority of the research and contributions of USGS staff were funded internally by the U.S. Department of Interior and funded incrementally by this project. Major results of this study were reported in the June 30, 2005 Topical Report and the July 25, 2005 Quarterly Report for the period of June 2004 through December 2004.

5.6 TASK 6.0: Reservoir and Fluids Characterization

University of Arizona
UA Principle Investigator: Robert Casavant
UA Co-Principle Investigator: Roy Johnson, Mary Poulton
UA Participating Scientists: Karl Glass, Ken Mallon
UA Graduate Students: Casey Hagbo, Bo Zhao, Andrew Hennes, Justin Manuel, Scott Geauner
UA Undergraduate Student Assistant: Greg Gandler

Certain prior accomplishments and plans were documented and summarized in Quarterly reports 15 and 16, respectively. Status update and planning meetings to discuss documentation of accomplished work were held December 7-8, 2006 at UA. The University of Arizona (UA) remains under a no-cost extension pending evaluation of accomplished work and results of Phase 3a stratigraphic test. December meeting discussions included Sagavanirktok correlations and mapping status through J. Manuel's thesis work. Additionally, 3 publications are in-preparation:

1. Expert System for Estimating Gas Hydrate Concentrations using Petrophysical Wireline Logs on the Alaskan North Slope
2. Using Thermal Conductivity Modeling and Wireline Petrophysical Logs to Identify Intrapermafrost Gas Hydrate
3. Estimating the Base of the Permafrost and Base of the Hydrate Stability Field Using Simulated Well Bore Temperature Logs

UA studies support the selection of the MtElbert prospect area for a stratigraphic test and data acquisition. UA studies also indicate that this MPU prospect is interpreted to contain gas hydrate-bearing reservoir sands. This prospect is interpreted on a structurally-high horst block near the eastern edge of the UA-interpreted "East basin", but within what may be the western portion of another Sagavanirktok depocenter basin. The frequency of current well control used in the East basin interpretation (since most well penetrations of the shallow Sagavanirktok interval occur within a few hundred feet of existing gravel production pads) may be less than the interpreted frequency of the fluvial-deltaic Sagavanirktok stratigraphic reservoir variation. Thus, a delineation well in the MtElbert prospect location will help assess both the structural and stratigraphic controls of gas hydrate accumulation within the shallow Sagavanirktok reservoir.

The MtElbert prospect location occurs above what are interpreted to be regionally wet Ugnu sands (below the regional Ugnu reservoir viscous oil to water contact). A petroleum system linkage between viscous oil biodegradation in the Ugnu to gas migration through the Ugnu top seal and into the shallower Sagavanirktok sands remains unproven, but is theorized by some researchers. The seismic interpretation clearly indicates gas hydrate-bearing sands in the Sagavanirktok interval as documented in prior reports. The MtElbert-01 stratigraphic test well was planned to penetrate the upper Ugnu above 4,000 feet TVDss to investigate this potential petroleum system linkage, but Tier 1 cost-cuts implemented to offset increased costs of oil-based mud and wireline logging necessitated reducing to a total depth of 3,000 feet TVDss.

UA plans to document the Phase 1-2 regional MPU, KRU, and PBU reservoir characterization studies of gas hydrate and associated free gas resources. The regional reservoir characterization is based primarily on well-log-based interpretations within the area-of-interest. A suite of maps is in preparation.

5.7 TASK 7.0: Drilling, Completion, and Production Lab Studies

University of Alaska Fairbanks (UAF)
UAF Principle Investigator: Shirish Patil
UAF Co-Principle Investigator: Abhijit Dandekar
UAF Research Professional: Narender R Nanchary
UAF Graduate Students: *Jason Westervelt, Stephen Howe,* Namit Jaiswal, Prasad Kerkar, Hemant Phale
UAF Undergraduate Student Assistant: Phillip Tsunemori

This section discusses gas hydrate research activities that were completed or are in progress between October 1, 2006 through December 31, 2006 at the University of Alaska Fairbanks (UAF). UAF remains under a no-cost extension and did not document significant accomplishments during the reporting period, but plans to apply experimental work in phase behavior, relative permeability, and formation damage to gas hydrate-bearing Sagavanirktok reservoir core samples acquired in Phase 3a.

Phase 1-2 study tasks were completed and documented in detail in Quarterly Reports 1-15. UAF is expected to continue to play a key role in Alaska gas hydrate research to address potential productivity issues. The gas-water relative permeability data for gas hydrate systems was studied in Phase 1 for reconstituted sediment samples from sands not within the Sagavanirktok formation since no samples of these sands were available. Studies of Sagavanirktok formation core samples acquired in Phase 3a would enable obtaining ANS-specific gas-water relative permeability data for gas hydrate systems. These field samples are critical inputs to the reservoir simulation work, as gas-water relative permeability data provides direct input to reservoir and fluid flow modeling. Additionally, issues related to the kinetic reaction parameters and ice formation reactions also need to be resolved to enable comparison of results with existing simulators such as the EOSHYDR TOUGH2. Experiments are expected to determine if formation of ice may inhibit or contribute to gas dissociation from gas hydrate during production and to compare the order of magnitude of heat released while forming ice to that of becoming resistant to gas flow. Similarly, there is also a need to investigate the phase behavior characteristics of gas hydrate systems in the field samples, as the prior studies focused mostly on synthetic samples. This is also an important aspect of reservoir simulation as this directly relates to the production of ‘additional’ gas from gas hydrate dissociation.

In Phase 3 studies, UAF is expected to play a role in analyzing core samples acquired from field work by measuring rock and fluid properties, helping design appropriate mud systems, assessing formation damage and core studies, while continuing the work on production modeling and economic studies.

5.7.1 Petrophysical and Other Physical Properties of Gas Hydrate Core Samples

No core samples were acquired during the reporting period.

5.8 Phase 3a Task 8.0: Plan and Implement Drilling of Stratigraphic Test Well

Detailed Phase 3a well plans were developed during the reporting period. A summary of work accomplished during the reporting period includes:

- Considered addition of short-term Drill-stem testing (DST) to data acquisition program
    - Worked with Schlumberger and Ryder Scott to develop viable DST plans
    - Reviewed DST from 1972 NWEileen-02 for insight to current plans
    - Evaluated DST plans with BP operations and wells group
    - Investigated and rejected non-rig well abandonment options
    - Arranged DST equipment options ($20K/day) contingency if program approved
    - Rejected DST option due to high ice-pad operations cost and abandonment concern regarding downhole Electrical Submersible Pump (ESP) cable/equipment
- Developed detailed core planning documentation in cooperation with experts from BP, Corion, and OMNI Lab
- Led/attended multiple meetings regarding well operations and data acquisition plans
    - Forwarded safety, policy, training, and procedure documents to all subcontractors
    - Completed coring, logging, wireline testing risk analyses and plans
    - Switched to oil-based (vs. water-based) chilled mud for operations and safety
    - Prepared field staff roster, assignments, and shift schedules
    - Finalized plans and contracts, permits, and materials acquisition
    - Documented risks, addressed concerns, and developed plans to mitigate risks
    - Rechecked surface, ice pad/road, and well bottom hole locations
    - Provided action reviews and coordinated well operations plans
    - Finalized logging-during-drilling, wireline, and MDT program plans
    - Finalized mud program and incorporated DrillCool, Inc. mudchilling system
    - Finalized core program and procedures and evaluated and selected vendors
        - Finalized core acquisition parameters with Corion (ReedHycalog)
        - Finalized core handling and processing program with OMNI and others
        - Finalized onsite data acquisition and core handling procedures
- Presented well plans to MPU ANS operations staff; visited MtElbert-01 MPU wellsite
- Implemented all materials acquisition for Phase 3a well operations

The planning and execution of a stratigraphic test well within the MPU Mt. Elbert prospect is an integral project objective. This objective is defined as Task 8.0 within Amendment 11 of the BP-DOE Cooperative Agreement:

“Task 8.0 - Plan and Implement Drilling of Stratigraphic Test Well:

Recipient will implement appropriate data acquisition consisting of a drilling and evaluation program based on a single vertical stratigraphic test well with appropriate logging, coring and

MDT testing of the previously documented "Mt. Elbert" or comparable prospect within the Milne Point Unit. The field activity will be designed to determine the validity of pre-drill seismically-based predictions of gas hydrate occurrence and reservoir quality and to collect other data as necessary to enable a decision whether or not to conduct future dedicated gas hydrate reservoir production testing on the Alaska North Slope. Recipient will maximize synergies with existing and planned ANS developments. Recipient will either plug and abandon the well before moving off or suspend the well with or without instrumentation for future use as an observation well"

5.8.1 Stratigraphic Test Engineering and Operations Procedure Summary

The well plan engineering and operations procedures were reviewed with the rig assignment to Doyon 14. This section briefly summarizes objectives for the 2007 gas hydrate stratigraphic test well within the MPU on the ANS. The priority of objectives are: 1. Wireline Logging, 2. MDT Pressure Testing, and 3. Core Acquisition. The Mt Elbert-01 well is being drilled as a Stratigraphic Test within Phase 3a of the BPXA-US Department of Energy (DOE) Gas Hydrate Cooperative Research Project. Core acquisition, processing, and transportation plans have also been prepared as additional documents in support of the well planning documentation for this well. Lessons learned from previous gas hydrate-bearing cored wells, such as the Mallik 1998 and Mallik 2002 onshore and certain offshore research programs are incorporated into the well planning, where applicable.

The program has been designed to deliver the primary objectives identified by the Gas Hydrate project research team and the MPU development team; it will be reviewed and refined through a number of meetings leading up to well spud in early February 2007. In addition, Job Risk Assessments (JRA) and dry-run pre-operations onsite training are planned prior to and during the wireline coring, logging, and MDT operations on the Doyon-14 rig.

MtElbert-01 is the first of three (2 are non-hydrate) planned appraisal wells to be drilled in MPU during the 2007 ice-pad exploration season. The primary objectives of this well include acquisition of approximately 400 to 600 feet of low invasion 3-inch whole wireline-retrievable core, wireline logging, and MDT testing within interpreted gas hydrate-bearing Sagavanirktok reservoirs beneath the Permafrost within the Eileen gas hydrate trend (Figures 1 and 2) to improve reservoir characterization and resource determination. This program will acquire the first conventional rig wireline core on the Alaska North Slope using an improved version of the ReedHycalog (Corion) Wireline Express tool that successfully retrieved, via wireline, the inner core barrel through the drill string in the Mallik 2002 gas hydrate project. A separate coring protocol document (Appendix B) gives technical justifications and methods for acquiring, subsampling, transporting, and storing core to meet the project objectives.

5.8.1.1 Project Summary

The U.S. Department of Energy (DOE) has awarded BPXA an additional $4,854,247 through up to end-2007 in contract amendments 11-16 to drill a Stratigraphic test and acquire data within Phase 3a of the Gas Hydrate Cooperative Research Agreement (CRA). Phase 3a was approved January 16, 2006 as a continuation of the gas hydrate research initially contracted with DOE on October 22, 2002. Phases 1 and 2 were completed by end-2005.

The CRA Phase 3a will provide further information regarding gas hydrate resource potential while building and maintaining mutual BP reputational and DOE relationship benefits. Key team researchers are retained with universities, government agencies, and consulting companies.

Phase 1-2 CRA results suggest 0-12 TCF could be recovered from 33 TCF in-place within shallow MPU/PBU/KRU gas hydrate reservoirs. The planned core and log data acquisition should help narrow the range of this recoverable resource uncertainty. Gas hydrate production would yield methane and fresh water, both of which have potential Alaska North Slope (ANS) use. Long-term, the gas could supplement export sales gas. Hydrate-sourced gas could also supply significant fuel for potential thermal recovery of the geographically-coincident 20-25 billion barrels viscous oil resources. Low-salinity water floods and/or steam-floods could use the fresh water. Gas hydrate reservoirs may also provide an attractive CO_2-sequestration option during future gas sales.

The CRA project is characterizing, quantifying, and evaluating the potential gas hydrate resources in the Prudhoe Bay Unit - Kuparuk River Unit - Milne Point Unit area and has selected The MtElbert prospect site to be drilled as a Phase 3a Stratigraphic Test within MPU in 2007. The project research and development includes:

- Phase 1-3: Characterize reservoirs and fluids to validate existing resource estimates and determine resource extent and connectivity in the area-of-interest
- Phase 2-3: Determine resource recovery factor and associated productivity and commerciality through reservoir and economic modeling
- Phase 2-3: Develop principles and practices to safely drill, complete, and produce or production test shallow gas hydrate and associated free gas resources
- Phase 2-3: Develop procedures and guidelines to determine the technical and economic feasibility of producing natural gas from gas hydrate-bearing formations
- Phase 3a: Drill and acquire data in a Stratigraphic Test of gas hydrate-bearing formations
- Phase 3b (unapproved): Perform long-term production testing within gas hydrate-bearing formations

BPXA and USDOE are partnering with the United States Geological Survey and collaborating with the ASRC Energy Services, the University of Arizona Tucson, the University of Alaska Fairbanks, Ryder Scott Co., APA Engineering, and others to develop reservoir and economic models, determine the technical feasibility of gas hydrate production, and potentially enable future exploration and field extension into this unconventional resource. The large magnitude potential in-place gas hydrate resource (33-100+ TCF; Figures 1-2) created industry-government-academic alignment to assess this potential resource beneath existing oil and gas facility infrastructure.

BPXA plans three off-ice appraisal wells / data acquisition programs within MPU in 2007. The gas hydrate appraisal is the first well and viscous oil appraisal wells within the northwestern area of the Milne Point Unit will comprise the latter two wells.

Core, logs, and MDT data will help determine the resource potential of methane hydrate within the study area. The determination of locally derived rock and reservoir properties data is considered critical for properly characterizing the Sagavanirktok formation for potential future reservoir development planning. Only a few feet of conventional core were acquired within the Eileen gas hydrate trend in the 1972 Northwest Eileen State #2 well, only very few full-suite wireline logs are available, and no MDT pressure testing has occurred within these intervals on the ANS.

The MtElbert prospect is one of 14 mapped gas hydrate prospects within the MPU that may contain a total of 600-700 BCF gas in-place. The prospect is mapped as a 3-way fault-bounded structural trap within the northwestern portion of the Eileen gas hydrate trend and may contain up to 90 BCF gas in-place (Figure 3). Figure 4 illustrates the surface location for the MtElbert-01 stratigraphic test well and ice pad.

Total cost of the well the MtElbert-01 Sagavanirktok drilling and core, log, and MDT data acquisition is estimated to be $4.1-4.8 MM, depending on operations contingency costs.

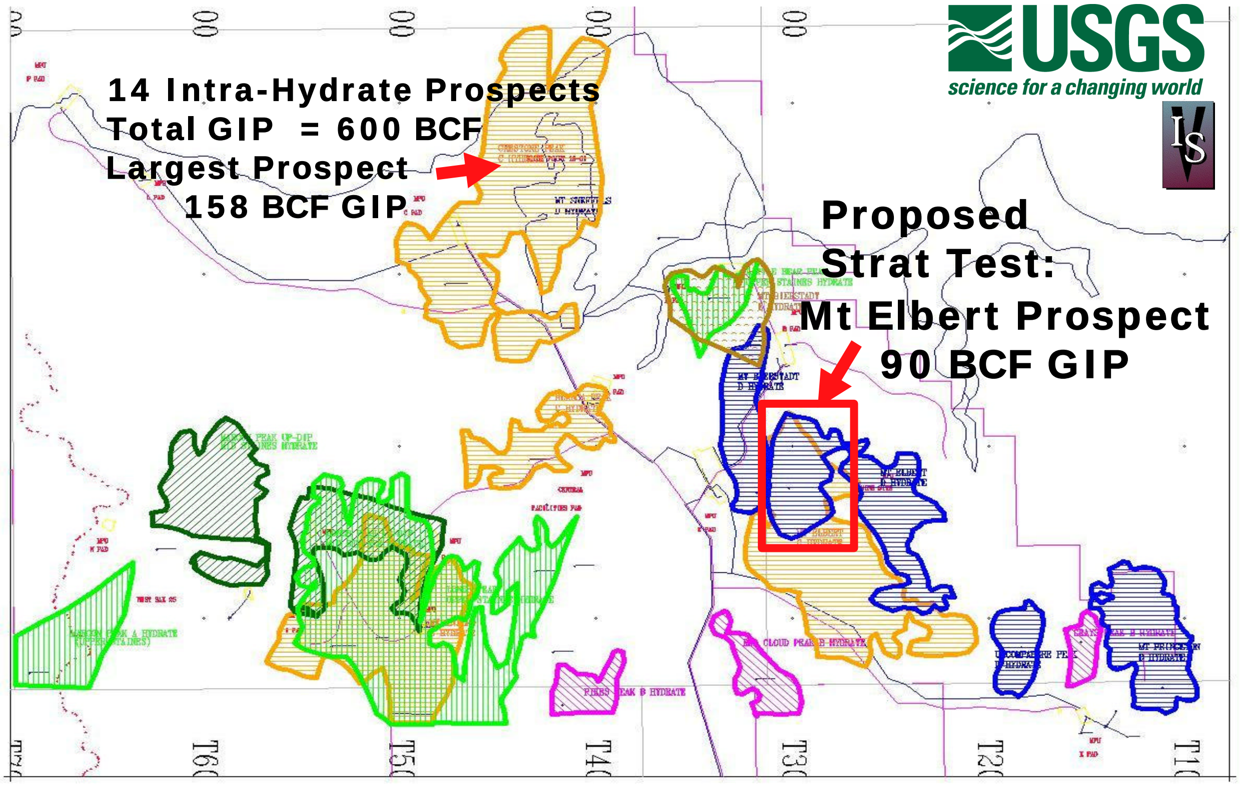


Figure 3: Gas Hydrate prospects within MPU

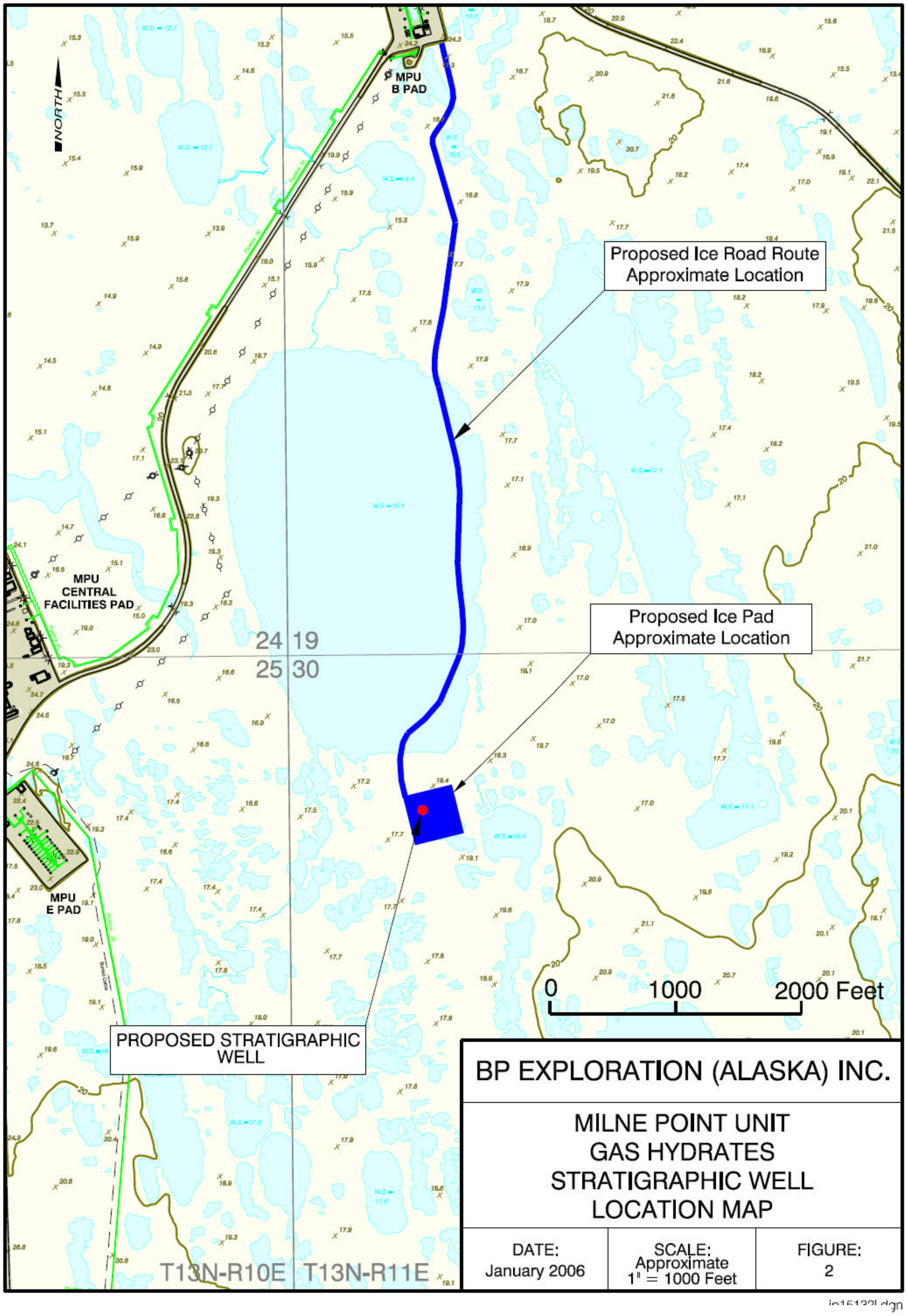
5.8.1.2 Drilling Requirements

The layout of core processing areas on Doyon-14 and the ice pad will be reviewed and agreed by the lead coring engineer and drilling supervisor. The diagram in Figure 5 shows the planned layout to indicate the scale of operations for general guidance.

Maintaining an in-gauge borehole with no to minimal washout is critical to maintaining safe operations and to acquiring high-quality core, log, and MDT data. In support of these safety and data acquisition objectives, a special mineral oil-based mud (MOBM) drilling fluid will be used and cooled in a special chilling unit connected to the mud system on Doyon-14. The chilled MOBM is expected to maintain both borehole and gas hydrate stability during drilling, coring, logging, and MDT operations. Surface casing is planned to be set in a shaly section just below base permafrost to maintain permafrost stability (Figure 6). A Draft of expected operations with contingencies is illustrated in Table 1.

Hrs	Cum Hrs	Detailed Operation Plan, Including Contingency Operations	Cum Days
18	18	Rig move from Milne S-Pad	0.8
36	54	MIRU. Install mud chiller, MWD, Corion wireline unit. Spot coring trailers. Test divert	2.3
36	90	PU/Rack back Corion DP. Spud well. Drill surface hole to 1950' md. Circ, POOH, LD BHA	3.8
18	108	Run and cement 9-5/8" surface casing	4.5
18	126	ND Diverter, NU wellhead/BOPE, Test BOPE.	5.3
12	138	RU and shake down coring equipment - dry runs in cased hole.	5.8
8	146	MU Corion insert BHA, RIH, test csg, drill 20', FIT to 11 ppg (need kick tolerance). Drill to core point ~2100'. CBU.	6.1
24	170	Swap to water free MOBM, activate DrillCool mud chillers	7.1
48	218	WL pull insert, install core barrel. Wireline core the hydrate zone ~ 600' to ~2700' (need to hi-grade interval)	9.1
8	226	WL install bit insert, drill 2700' to 3000' TD. Condition hole, POOH LD tools (no LWD/MWD)	9.4
		Ream out 7 7/8" hole to 8 3/4" from surface casing to 3000' TD	
24	250	RU E-line, run openhole logs - 3 trips	10.4
8	258	BOP Test (a bit early but prior to cleanout run for MDTs)	10.8
8	266	8-1/2" bit cleanout run to TD, prior to MDT	11.1
48	314	DPC MDT x trips, 4 stops, 12 hour stops	13.1
8	322	**Contingency** 8-1/2" cleanout run for 7" liner.	13.4
24	346	**Contingency** 7" liner and cement, ~1200' long (place LC, or PBTD 100' below lowest hydrates test zone - easy to P&A)	14.4
18	364	**Contingency** GR/JB to TD. RU E-line, USIT/CBL. perforate Hydrates	15.2
24	388	**Contingency** E-line cased hole MDT (assumes all 48 hrs from failed DPC MDT'ing was not yet consumed)	16.2
24	412	**P&A -** assumes openhole - RIH w/ stinger to 200' below hydrates, spot 100' viscous pill,	17.2
	412	**P&A -** PUH to 100' below hydrates and set a 500' balanced cement plug from 100' below the hydrate zone	17.2
	412	**P&A -** POOH to 2000', circulate out and reload another 500' cement plug, up to 1500'	17.2
	412	**P&A -** WOC for 6 hours, tag plug per AOGCC (LD singles while WOC)	17.2
	412	**P&A -** POOH LDDP. LD any remaining pipe in derrick	17.2
6	418	**P&A -** RIH to 350', spot a 100' weighted viscous pill from 350' to 250'. Pump cement to surface. C/O top 25', w/ diesel	17.4
8	426	**P&A -** ND BOPE and wellhead. Tag TOC.	17.8
18	444	**P&A -** Cut 9-5/8" and 20" conductor at least 3' below tundra. Weld on prefab'ed marker plate.	18.5
12	456	RDMOL Doyon 14	19.0
72	528	**Contingency NPT Time - 3 days**	22.0
		Abandon well cellar and conductor section per AOGCC regs (non-rig)	
		Clean up location - MPU Environmental site inspection	

Table 1: DRAFT (1/24/07) Planned Well Operations and Contingencies



5

Figure 4: Surface Location Map Showing Ice Road and Pad within MPU Field Area

5.8.1.3 Coring Requirements

Appendix B contains a complete summary of the core procedure documentation. The MtElbert-01 well is planned to acquire 400-600 feet of wireline-retrievable core from 2-3 major reservoir sand intervals that are interpreted from the seismic data to contain gas hydrate within the Sagavanirktok intervals shown in Figure 6. The reservoir properties and lateral continuity of the Sagavanirktok zones are relatively unknown. The core point in this well will occur just below the surface casing point set in the shalier section below Zone E just prior to penetrating the top of Zone D (Figure 6). The projected core point is 2000 feet TVDss, but may be subject to change if the well plan requires a final modification following correlations from the MWD logs in the surface hole.

Once the Sagavanirktok zone D and C-sands have been cored, the coring in the Sagavanirktok formation is planned to continue through the Zone B reservoir interval, if time permits (Figure 6). Zones D and C are currently interpreted to be fluvial-deltaic sands and Zone B is interpreted to be marine. These zones are interpreted to contain gas hydrate, water, and possibly free gas as pore-filling fluid phases.

The core point for the MtElbert-01 well will be picked by the wellsite geologists based on MWD log correlations from the adjacent MPU E-26 and B-01, B-02, B-22, and other E-pad offset penetrations. The MtElbert-01 well LWD logging tool will be placed as close to the bit as possible in the surface hole to minimize core depth point prediction uncertainty.

The criteria for ending the planned Sagavanirktok formation core program are as follows:

1. The full 600 feet of Zone D and Zone C through base Zone B interval core has been recovered as illustrated in Figure 6, or
2. If coring across the targeted Sagavanirktok intervals have not been completed but the core acquisition AFE limit has been reached (i.e. 48 hours in base-plan, with up to 24 hour contingency time)

The well track is planned to be vertical throughout this interval. The purpose of obtaining the core is to characterize the following reservoir properties to help reduce subsurface uncertainties from which an appropriate understanding of gas hydrate-bearing reservoir properties can be ascertained.

The MtElbert-01 core onsite subsampling analysis objectives are:

1. Confirm gas hydrate and reservoir characterization interpretation
2. Obtain whole-round cores for porosity, permeability, and fluid saturations determination for log calibration, and potential resource assessments.
3. Sample mineralogy and lithology for log calibration, and understanding formation physical and mechanical properties
4. Sample gas hydrate and pore water geochemical and microbiological properties to understand the origin of gas hydrate and implications for vertical and lateral compartmentalization within variable lithologies.
5. Sample biostratigraphic markers, which will aid in constraining and/or defining regional stratigraphic correlation horizons.

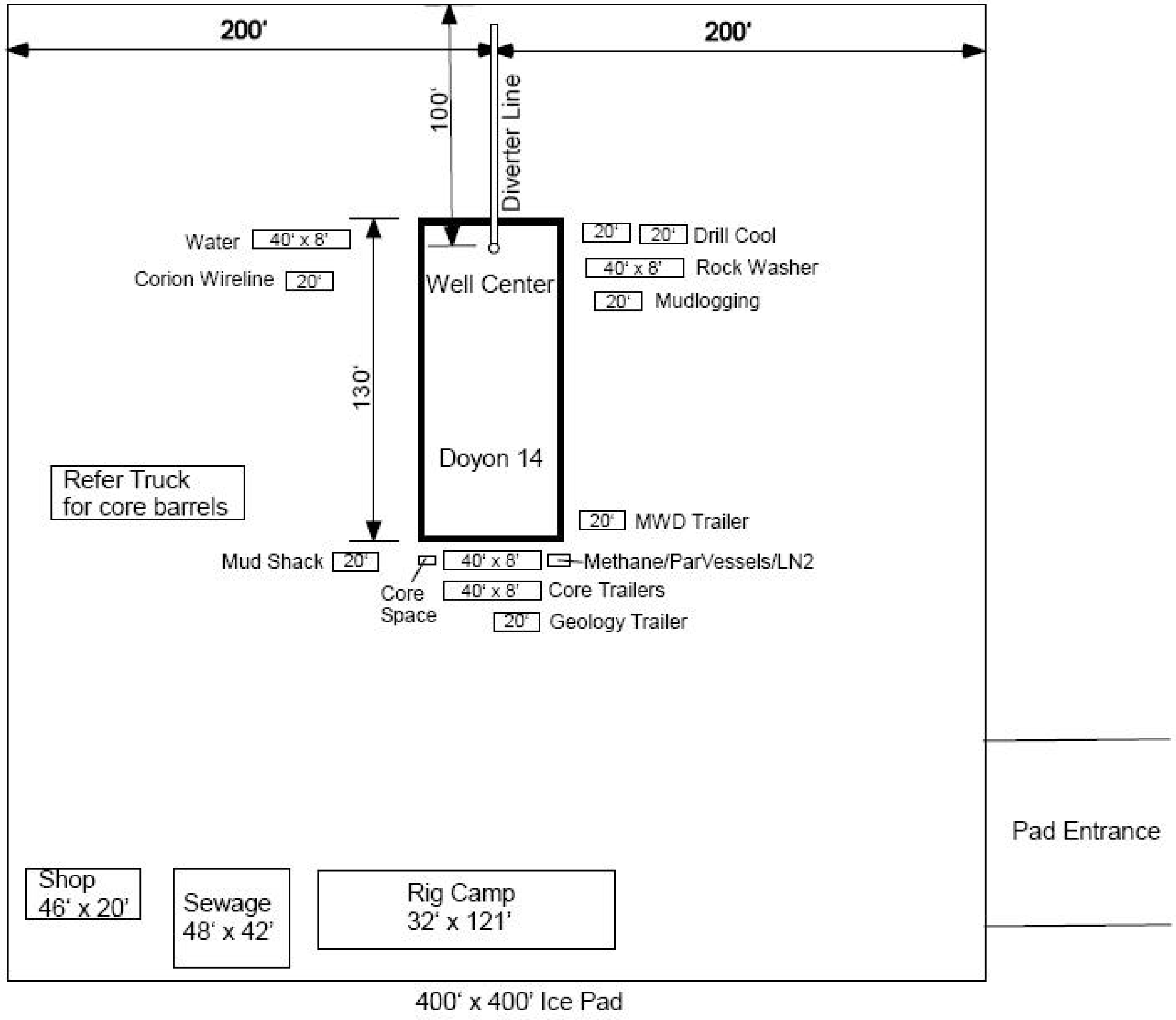
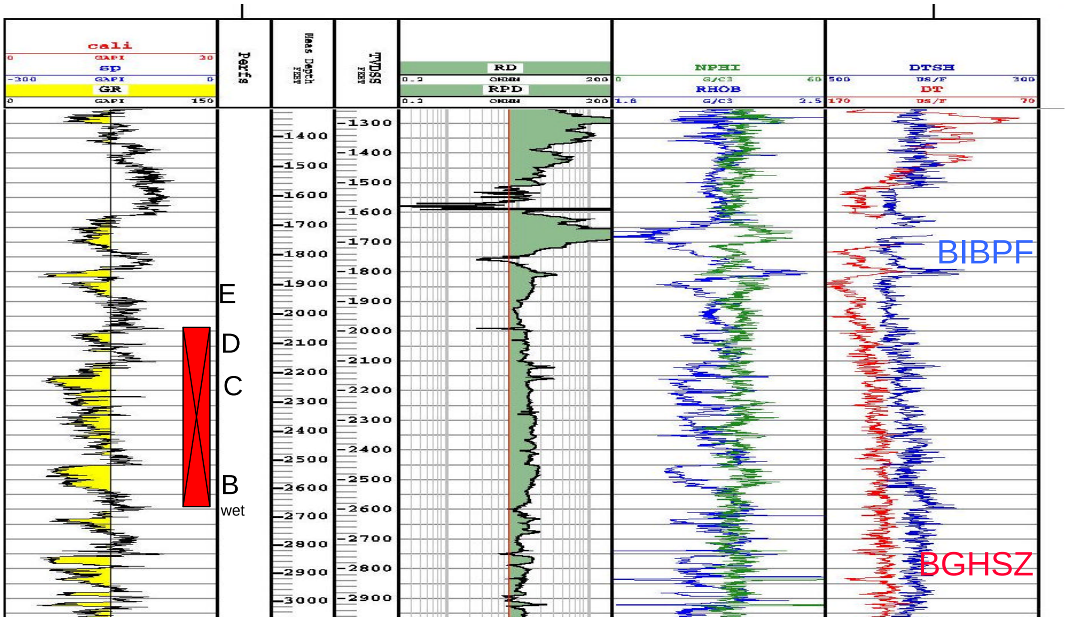


Figure 5: Ice Pad and Rigsite layout diagram. Note that Rig Camp and facilities may alternatively be staged on MPB-pad, approximately 1 mile to the north (Figure 4).

Core will also provide critical information on reservoir quality, interpreted reservoir lateral continuity, reservoir fluids, hydrocarbon in-place, resources, potential deliverability, well placement and drillability. Specific post-well core studies will include the following (subject to budget availability):

- Core-derived Rw/Sw (gas-hydrate-in-place)
- Sedimentology (well placement, reserves)
- Poroperm (reserves, well productivity)
- Reservoir quality (well placement)
- High resolution biostratigraphy (drilling)
- Vertical and horizontal heterogeneity description (compartments, depletion plan)
- Coreflood tests (relative permeability)
- Petrophysical tests



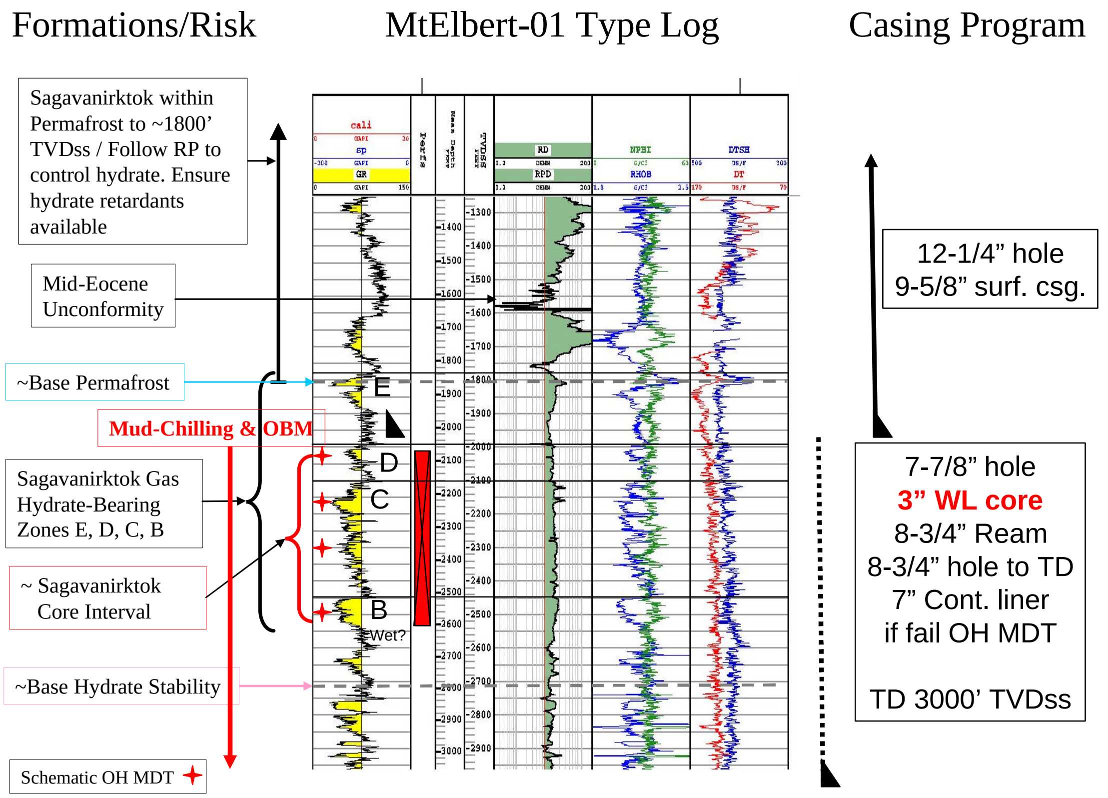


Figure 6: MPE-26 Type Log showing planned intervals of wireline log and core data acquisition between Base of Ice-Bearing Permafrost (BIBPF) and Base Gas Hydrate Stability Zone (BGHSZ) and planned drilling/casing program.

Primary Risks / Impacts / Mitigations to good coring performance and the overall well objectives on MtElbert-01 are detailed in the Core Risk Register. The top 6 include:

1. **Stage:** Planning and preparation / **Risk**: Coring equipment and personnel not available when needed (Corion's wireline system, Drill Cool mud chilling system, USGS/DOE equipment and supplies, Core trailers) / **Impact**: Unable to core well, possible rig standby waiting on equipment / **Mitigation**: Prepare detailed coring plan. Work with vendors to confirm equipment and personnel are available (and properly certified and trained for slope). Prepare checklist and distribute. Prepare checklist for training and slope clearance.
2. **Stage:** Planning and preparation / **Risk**: Coring procedure and processes and core handling procedure poorly understood leading to HSE incident / **Impact**: Cannot proceed with work or HSE impact / **Mitigation**: Proper FEL planning and documentation, proper ATP. Proper JSA/JRA at rigsite pre-core with dress rehearsal. Detailed coring pre-spud on rig with rig and coring crews.
3. **Stage:** Operations **/ Risk:** Mud chiller fails / **Impact:** Cannot proceed with drilling/coring well, poor data acquisition, poor borehole conditions, loss of borehole, potential well control issue / **Mitigation**: DrillCool equipment must be checked out and working ahead of time, and working at Doyon14. On location when Doyon14 moves on ice pad for spud ~Feb. 2nd.
4. **Stage:** Operations **/ Risk:** Core point picked too shallow or too deep (core point based on isopach ahead from casing shoe) / **Impact:** Core the wrong interval. Pick too shallow and not enough time to obtain 600' of cored interval. Pick too deep and drill up main cored interval. Don't have enough wiggle room in timing to have mis-picked core point / **Mitigation**: Have rig geologists and USGS/DOE in agreement for core point.
5. **Stage**: Operations / **Risk**: Swabbing during POOH / **Impact**: Well control incident / **Mitigation**: Prepare tripping guidelines to include maximum speed per wireline run, pump out of open hole. Model swab prior to coring and develop tripping schedule. There is a great deal of flexibility here. If the top valve on the diverter sub is closed, wireline can be pulled at up to 200 feet per minute and likely not swab the well. If the valve is left open, approximately 10 gallons may be swabbed. There is no perceived downside to the leaving the valve closed and pulling at the above rate. The rates are dealing with gas expansion in the core, if no free gas is expected, then pulling at 200 feet per minute could occur with minimal to no swabbing.
6. **Stage**: Operations / **Risk**: Gas liberation at rig floor / **Impact**: HSE incident, poor core quality / **Mitigation**: Prepare tripping guidelines to include maximum speed per stand and per #5 Corion input. Chilled MOBM.

Additional concerns include, but are not limited to:

- Jamming of the semi-consolidated water-bearing reservoir sands within the Sagavanirktok formation,
- Poor recovery of the gas hydrate-bearing reservoir intervals,
- Poor displacement of water based drilling mud with oil-based coring fluid or excess water in MOBM system,

- Borehole problems due to mud-chilling difficulties or gas dissolution from gas hydrate or associated free gas-bearing formations,
- Core face obscured by opaque oil-based mud with black Gilsenite additive causing difficulty in subsampling

All Risks to coring performance will be examined in detail and prevention/mitigation agreed with the operations team during the pre-coring risk register assessment. Above all, MtElbert-01 coring operations must be done without hurting people or damaging the environment in any way. BP HSE practices will be rigorously followed at all times and if anyone sees any cause for concern regarding procedures described in this or the primary core plan document, they should let the authors or BP management know immediately.

5.8.1.4 Logging Requirements

A primary objective of the stratigraphic test is to acquire high-quality wireline logging across the interpreted gas hydrate-bearing intervals of the shallow Sagavanirktok reservoir sands and shales. Since the well is planned to be near-vertical, wireline logs are planned to acquire high-quality gas hydrate-bearing reservoir petrophysical data, provided that the mud-chilling operations maintain adequate borehole stability and in-situ conditions (preventing borehole washouts and gas hydrate dissociation during drilling, coring, and data acquisition operations). Wireline logs would be run from approximately 1,950 to 3,000 feet (or TD) in the “production” hole below surface casing below BIBPF as shown in Figure 6. The MPE-26 type log shown in Figure 6 is directly beneath MPU E-pad within the shallow zones of interest. MPE-26 is on MPE-pad approximately 1,500 feet west of the proposed Mt Elbert-01 well location (Figure 4). Wireline logs planned would include gamma-ray, resistivity, neutron-density in the “platform-express” along with dipole sonic (with shear wave data), nuclear magnetic resonance (NMR), RtScanner, and oil-based formation micro-imager (OBMI) to help determine gas hydrate-bearing reservoir properties. Planned data acquisition is summarized in Table 2.

Wireline Logging Runs from Surface Casing to TD
Run-1
PEX - Platform Express
AIT - Array Induction-SP Log
RtScanner (AIT or RtScanner)
Electromagnetic Propagation Tool Log
Run-2
DSI - Dipole Shear Imager Log - expert mode; stonely
GR - Gamma Ray Log
OBMI - Formation MicroImager for oil-based mud
Run-3
CMR - Combinable Magnetic Resonance Tool
NGT - Spectral Gamma Ray Log
ECS - Elemental Capture Sonde
Run-4
MDT Open Hole – 2 test points per sand (2 sands expected) – up 10 hrs/each; cased hole MDT contingency

Table 2: Planned Wireline Logging Runs

5.8.1.5 MDT Pressure Testing Requirements

During the 2002 Mallik gas hydrate program, Modular Dynamic Test (MDT) data provided valuable insights into the potential productivity of gas hydrate-bearing reservoir sands (Figure 7; Courtesy GSC, Bulletin 585). These tests revealed for the first time that movable connate waters could be produced through the MDT tool within gas hydrate-saturated reservoir sand intervals. This revelation may importantly indicate an ability of the gas hydrate-saturated reservoir to transmit a pressure pulse with offtake of mobile connate waters. The MtElbert-01 MDT tests are expected to yield important data regarding gas hydrate-bearing reservoir connate water mobility, permeability, relative permeability, dynamic permeability (changing during dissociation of gas hydrate), and other data in combination with core and wireline logs. Analysis of this data is anticipated to help promote a better understanding of the potential productivity and potential production methods of these gas hydrate-bearing reservoirs. Three to four separate MDT sites within 2-3 interpreted gas hydrate-bearing reservoir sands are anticipated to be tested for up to 10 hours per test (Figure 6).

The MDT plan will be flexible to account for onsite interpretations and an ability to conduct pressure tests both within and outside of gas hydrate equilibrium conditions. The MDT tool basically allows a limited down-hole production test, which can yield this very important data. The MDT testing is planned for a dual-packer, open-hole approach. This approach is commonly run on the North Slope, but has never before been attempted within a gas hydrate-bearing interval in an open hole. A contingency 7” liner is planned to allow running of MDT in cased hole should the preferred open hole method have unacceptable operational difficulties. Planning meetings have been held with Schlumberger MDT experts in Houston and have included the team that designed and implemented the Mallik 2002 MDT program. The head of the Mallilk 2002 MDT testing program, Steve Hancock, APA Engineering, will also be onsite to enable maximum data acquisition and flexibility. MDT results will be applied to reservoir model calibration and will help understand the important gas hydrate-bearing reservoir relative and dynamic dissociating permeabilities, all very important parameters to model production potential.

5.8.1.6 Safety

Chilled (0 to 4 degrees Centigrade) mineral oil-based mud drilling fluid is critical to maintaining borehole stability, safe operations, and high-quality data acquisition. Coring is a non-routine activity; most of the below safety considerations, therefore, apply primarily to the coring operations and associated activities.

- Core point will be picked within the interpreted gas hydrate-bearing reservoir section: geologists, mudloggers, and driller should work closely together to ensure effective well control.
- During wireline retrieval of core, care must be taken to not “swab” excessive pore fluids up the drill-string. This interval has not been penetrated at this location and the exact nature of the pore fluids, while interpreted to contain gas hydrate, is not known; pore fluids may include water, gas hydrate, and/or free gas.
- Well control and assurance of delivery of the total objectives of the well will take precedence over geological core acquisition and termination criteria.

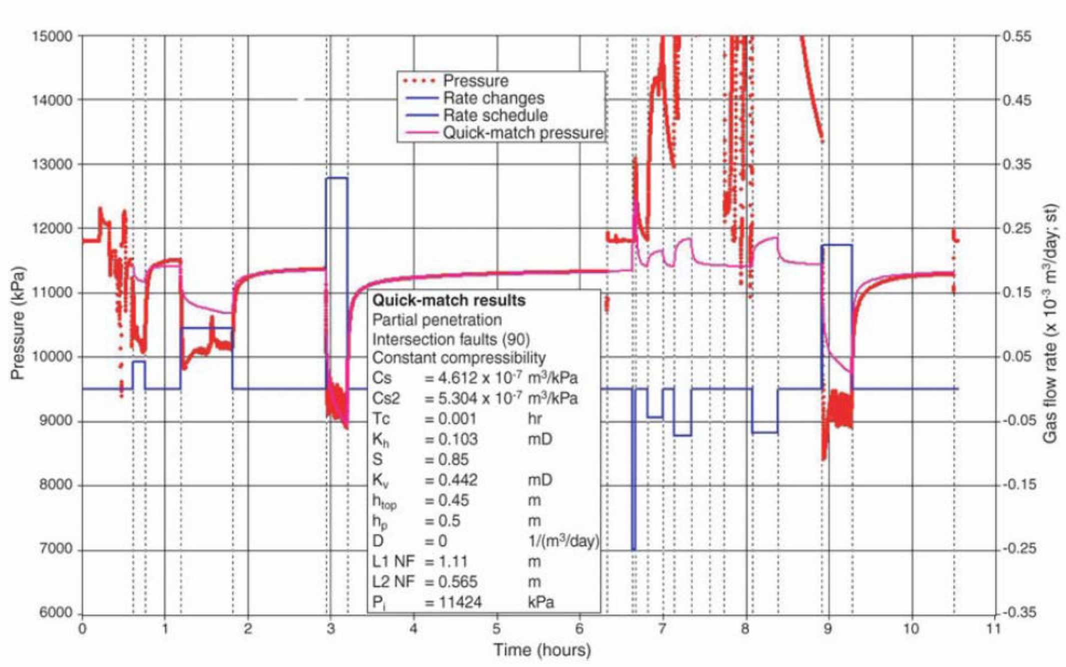


Figure _ 7. *Simulation of pressure history using the interpreted formation parameters from the third (i.e. the longest) pre-minifrac build-up period, MDT-2 test (gas hydrate zone at 1089.8 m KB), JAPEX/JNOC/GSC et al. Mallik 5L-38 gas hydrate production research well. Abbreviations: Cs, wellbore-storage coefficient (initial); Cs2, wellbore-storage coefficient (final); D, turbulent-skin coefficient; h_p, perforated interval; h_{top}, distance from top of formation to top of perforation; K_h, permeability (horizontal); K_v, permeability (vertical); L1 NF, distance to first no-flow boundary; L2 NF, distance to second no-flow boundary; m(p), pseudopressure; P_i, initial reservoir pressure; S, skin damage; st, standard conditions; Tc, time to end of initial wellbore-storage calculation.*

1. Coring will commence in open reservoir and well control requirements take precedent over technical recommendations made for improved coring practice.
2. Coring is not a routine activity, the coring engineer, core specialist, core shift team leads, and BP Operations Geologist will lead Job Risk Assessments (JRA's) and discussions with the rig crew involved to ensure that safe and effective procedures are used before picking up the core barrel and beginning coring.
3. JRAs will be reviewed with each crew as program and shift changes occur.

- The core barrel will be large diameter within drillpipe, calculate the wireline-retrievable tripping rates to prevent swabbing.
- Normal drillfloor procedure for safe tripping and wire-lining is required.
- The reservoir sections may be cored with moderate overbalance so the adoption of procedures to avoid differential sticking of the coring assembly is essential until BHA is safely tripped into the surface casing.
- All core handling presents a manual handling risk. Core handling operations will be carefully reviewed with the team, and all risks eliminated or minimized. Manual handling

refresher training will be performed with the team before the first core is handled, and then will be refreshed as required.

1. Core laydown is not a routine activity. The coring engineer will lead a Job Risk Assessment and discussion with the rig crew involved to ensure that safe and effective procedures are used before beginning the core lay-down.
2. Any misalignment of the inner tube during the cutting and the application of the shear boot may result in dropping the core onto the drill floor. This activity must therefore be conducted with great care.
3. Stringent precautions for heavy lifting must be followed with care – this is one of the most potentially dangerous parts of the whole coring operation.

- Gas monitoring (sniffers) will be provided by BP HSE in the core processing trailer(s) to provide assurance for electrical or non-intrinsically safe equipment operations during hot-work permitted operations; detailed protocols will be developed onsite during JRA's.
- The core handling will involve cleaning the oil-based mud from the outside surface of the core. Proper PPE, wiping rags, and rag disposal must be followed to eliminate any environmental impacts of this operation.
- The core will be cut with chisel and hammer; proper PPE and precaution must be used to avoid rock chipping hazard and potential eye damage.
- Certain subsamples will be removed from the Corion processing trailer, marked with Styrofoam insert, and destroyed in the Core Press to obtain pore water samples. The Press operation, while simple, must be properly used and adequately cleaned between samples.
- Appropriate caution should be applied to the required compressed air line for the presses in the geo trailer. Note that if air line is needed to the cold trailer that it will not last very long in cold environment (i.e. pneumatic saw to cut inner barrel tabs). This issue will need to be worked out onsite.
- Appropriate caution should be applied to the required outdoor methane station and a nitrogen station near the core trailer. The methane and nitrogen bottles should be stabilized using a standard bottle rack assembly and protected from the elements by placing them on the leeward side of the trailer and possibly constructing a temporary shelter, if needed.
- Core barrels have tabs which require cutting using a small abrasion air saw which must only be used by qualified operators (suppliers) with appropriate personal protective equipment including gloves, goggles, dust mask and earplugs. All non-essential staff should stand clear. A hot-work permit must be maintained for electrical equipment in the presence of potential out-gassing from hydrate dissociation of the core.
- Core processing is a non-routine activity. Pre-job briefings and training will be given to any staff who temporarily assist (e.g. rig crew, mudloggers).
- Team work hours will be monitored and a 12-hour shift system implemented. The baseplan is that no one should need to work longer than 12 hour days with a maximum of 16 hours. The baseplan for 24-foot core acquisition requires a 12 man team for processing within this framework (2 12-hour 6-man shifts) as documented in the below time estimate. This team of 12 is needed to maintain safe work hours for 2-3 days of successive 24 foot cores with approximately 90 minutes between cores. A 30-90 minute shift change-over time will be required during each shift change, depending on operations and difficulties.

- Core acquisition turn-around is expected to take 75 to 90 minutes per 24 foot core with the Corion system at optimum usage. Core processing and subsampling is estimated to require 60 minutes per 24 foot core.
- The planned MtElbert-01 core operation will be the longest yet in MPU experience with up to 600 feet of core (25 24-foot cores). Change out of team members over the anticipated 2-3 day coring time will be managed to minimize loss of learning and impact of handover.
- A number of air-lines and power cables will be routed to the core processing area and these must be properly located and connected. They must not constitute a trip hazard.
- All core processing activities must be discussed with and approved by the BP Drilling Supervisor before work begins. Proper permits must be obtained for any specialized procedures and equipment. Proper BP authorization is required for special required equipment such as power saws, centrifuge, rock press, etc.

5.8.1.7 Mudlogging Requirements

- Mud-logging interval is from surface to TD (~3000’ TVDss)
- Gas-detection is required from surface to TD
- Gas chromatograph from surface to TD
- Catch and describe samples at the following intervals:
  - 60 foot spacing from 0 to 1,900’ TVDss (Surface Casing Point)
  - 30 foot spacing from 1,900’ TVDss to TD – see also below Special Sampling Requirements for this interval
- Head space gas samples
- Reporting requirements as in pdf documents attached (regular morning report & lithology/gas logging)
- Washed cuttings for the State per State AOGCC requirements for new pad
- Aerosol cans and isotubes, production hole, only where gas shows 5 times over background and additional samples every 10 feet in the anomaly; Some of these may go through later ARMIS analyses, to be determined
- Recommend paired samples (i.e., one arousal cans and one isotube together) on every gas (total gas) anomaly about 5 times over background. Take additional paired samples in a thick anomaly about every 10 feet

- Canned Sample Cuttings: 60 foot spacing from 60 to 1900’ (surface)
  30 foot spacing from surface to TD
- Procedure: Obtain drill cutting samples for geochemical analysis and preserve the samples in pint or quart size paint cans as described below. The cuttings should be collected directly from the shaker table with a trowel. The sample should be collected as a single "grab" sample not a composite of the entire interval.

- Sampling Description:
  1. Collect cuttings directly from the shaker table using trowel.

2. Place the cuttings in a pint size can (provided) and fill the can to half full (do not add water).
3. Add a teaspoon of table salt, which is as bactericide (provided), to cuttings.
4. Wipe can rim clean.
5. Seal can with lid.
6. Label can (depth and well name), both on the side and the bottom of the can.
7. Turn the cans upside down and freeze. The samples will be shipped in provided coolers. During storage the samples should be frozen if possible.

6.0 CONCLUSIONS

The first dedicated gas hydrate coring and production testing well, NW Eileen State-02, was drilled in 1972 within the Eileen gas hydrate trend by Arco and Exxon. Since that time, ANS methane hydrates have been known primarily as a drilling hazard. Industry has only recently considered the resource potential of conventional ANS gas during industry and government efforts in working toward an ANS gas pipeline. Consideration of the resource potential of conventional ANS gas helped create industry - government alignment necessary to reconsider the resource potential of the potentially large (44 – 100 TCF in-place) unconventional ANS methane hydrate accumulations beneath or near existing production infrastructure. Studies show this in-place resource is compartmentalized both stratigraphically and structurally within the petroleum system.

The BPXA – DOE collaborative research project enables a better understanding of the resource potential of this ANS methane hydrate petroleum system through comprehensive regional shallow reservoir and fluid characterization utilizing well and 3D seismic data, implementation of methane hydrate experiments, and design of techniques to support potential methane hydrate drilling, completion, and production operations.

Following discovery of natural gas hydrate in the 1960-1970’s, significant time and resources have been devoted over the past 40 years to study and quantify natural gas hydrate occurrence. However, only in the past decade have there been significant attempts to understand the potential recoverability of methane from hydrate. Although significant in-place natural gas hydrate deposits have been identified and inferred, estimation of potential recoverable gas from these deposits is difficult due to the lack of empirical or even anecdotal evidence.

The potential to induce gas hydrate dissociation across a broad regional contact from adjacent free gas depressurization is demonstrated by the results of the collaborative BPXA-LBNL pre-Phase 1 scoping reservoir model (presented in the March 2003 Quarterly report and technical conferences) and corroborated by the results of continued UAF and Ryder Scott reservoir model research as presented in Section 5.9 of the December 2003 Quarterly report.

The possibility to induce in-situ gas hydrate dissociation through producing mobile connate waters from within an under-saturated gas hydrate-bearing reservoir establishes saturation and permeability as key variables which, when better understood, could help mitigate productivity uncertainty. A schematic potential development screening study was undertaken to set ranges on the potential resources that might one day be recovered (if production is technically and economically feasible) given various possible production scenarios of the ANS Eileen gas hydrate trend, which may contain up to 33 TCF gas-in-place. Type-well production rates modeled at 0.4-2 MMSCF/d yield potential future peak field-wide development forecast rates of up to 350-450 MMSCF/d and cumulative production of 0-12 TCF gas. Individual wells would exhibit a long production character with flat declines, potentially analogous to Coalbed Methane production.

Results from the various scenarios show a wide range of potential development outcomes. None of these forecasts would qualify for Proved, Probable, or even Possible reserve categories using the SPE/WPC definitions since there has yet to be a fully documented case of economic production from hydrate-derived gas. Each of these categories would, by definition, require a positive economic prediction, supported by historical analogies, prudent engineering judgment, and rigorous geological characterization of the potential resource before a decision on an actual development could proceed.

Approved field operations will enable acquisition of gas hydrate-bearing reservoir data within Phase 3a stratigraphic test studies. A key part of this analysis will be acquisition cores and wireline logging of gas hydrate-bearing reservoir sands and associated sediments. The wireline logging is planned to include Modular Dynamic Testing (MDT). Analysis of the core, log, and MDT results should help reduce the uncertainty regarding gas hydrate-bearing reservoir productivity and may lead to Phase 3b gas hydrate production test studies, although these Phase 3b studies are not currently approved.

7.0 PROJECT AND RELATED REFERENCES

7.1 General Project References

Casavant, R.R. and others, 2003, Geology of the Sagavanirktok and Gubik Formations, Milne Point Unit, North Slope, Alaska: Implications for neotectonics and methane gas hydrate resource development, AAPG Bulletin.

Casavant, R.R. and Gross, E., 2002, Basement Fault Blocks and Subthrust Basins? A Morphotectonic Investigation in the Central Foothills and Brooks Range, Alaska, at the SPE-AAPG: Western Region-Pacific Section Conference, Anchorage, Alaska, May 18-23, 2002.

Casavant, R.R. and Miller, S.R., 2002, Tectonic Geomorphic Characterization of a Transcurrent Fault Zone, Western Brooks Range, Alaska, at the SPE-AAPG: Western Region-Pacific Section Conference, Anchorage, Alaska, May 18-23, 2002.

Collett, T.S., 1993, “Natural Gas Hydrates of the Prudhoe Bay and Kuparuk River Area, North Slope, Alaska”, The American Association of Petroleum Geologist Bulletin, Vol. 77, No. 5, May 1993, p. 793-812.

Collett, T.S., 2001, Natural-gas hydrates: resource of the twenty-first century? In M.W. Downey, J.C. Treet, and W.A. Morgan eds., Petroleum Provinces of the Twenty-First Century: American Association of Petroleum Geologist Memoir 74, p. 85-108.

Collett, T.S., 2001, MEMORANDUM: Preliminary analysis of the potential gas hydrate accumulations along the western margin of the Kuparuk River Unit, North Slope, Alaska (unpublished administrative report, December 6, 2001).

Collett et al., 2001, Modified version of a multi-well correlation section between the Cirque-2 and Reindeer Island-1 wells, depicting the occurrence of the Eileen and Tarn gas hydrate and associated free-gas accumulations (unpublished administrative report).

Collett et al., 2001, Modified version of a map that depicts the distribution of the Eileen and Tarn gas hydrate and associated free-gas accumulations (unpublished administrative report).

Collett, T.S., 2002, Methane hydrate issues – resource assessment, In the Proceedings of the Methane Hydrates Interagency R&D Conference, March 20-22, 2002, Washington, D.C., 30 p.

Collett, T.S., 2002, Energy resource potential of natural gas hydrates: Bulletin American Association of Petroleum Geologists, v. 86, no. 11, p. 1971-1992.

Collett, T.S., and Dallimore, S.R., 2002, Detailed analysis of gas hydrate induced drilling and production hazards, In the Proceedings of the Fourth International Conference on Gas Hydrates, April 19-23, 2002, Yokahama, Japan, 8 p.

Digert, S. and Hunter, R.B., 2003, Schematic 2 by 3 mile square reservoir block model containing gas hydrate, associated free gas, and water (Figure 2 from December, 2002 Quarterly and Year-End Technical Report, First Quarterly Report: October, 2002 – December, 2002, Cooperative Agreement Award Number DE-FC-01NT41332

Geauner, J.M., Manuel, J., and Casavant, R.R., 2003, Preliminary subsurface characterization and modeling of gas hydrate resources, North Slope, Alaska, , in: 2003 AAPG-SEG Student Expo Student Abstract Volume, Houston, Texas

Howe, Steven J., 2004, Production modeling and economic evaluation of a potential gas hydrate pilot production program on the North Slope of Alaska, MS Thesis, University of Alaska Fairbanks, 141 p.

Hunter, R.B., Casavant, R. R. Johnson, R.A., Poulton , M.., Moridis, G.J., Wilson, S.J., Geauner, S. Manuel, J., Hagbo, C., Glass, C.E., Mallon, K.M., Patil, S.L., Dandekar, A., And Collett, T.S., 2004, Reservoir-fluid characterization and reservoir modeling of potential gas hydrate resource, Alaska North Slope, 2004 AAPG Annual Convention Abstracts with Program.

Hunter, R.B., Digert, S.A., Casavant, R.R., Johnson, R., Poulton, M., Glass, C., Mallon, K., Patil, S.L., Dandekar, A.Y., and Collett, T.S., 2003, “Resource Characterization and Quantification of Natural Gas-Hydrate and Associated Free-Gas Accumulations in the Prudhoe Bay-Kuparuk River Area, North Slope of Alaska”, Poster Session at the AAPG Annual Meeting, Salt Lake City, Utah, May 11-14, 2003. Poster received EMD, President’s Certificate for Excellence in Presentation.

Hunter, R.B., Pelka, G.J., Digert, S.A., Casavant, R.R., Johnson, R., Poulton, M., Glass, C., Mallon, K., Patil, S.L., Chukwu, G.A., Dandekar, A.Y., Khataniar, S., Ogbe, D.O., and Collett, T.S., 2002, “Resource Characterization and Quantification of Natural Gas-Hydrate and Associated Free-Gas Accumulations in the Prudhoe Bay-Kuparuk River Area on the North Slope of Alaska”, presented at the Methane Hydrate Inter-Agency Conference of US Department of Energy, Washington DC, March 21-23, 2002.

Hunter, R.B., Pelka, G.J., Digert, S.A., Casavant, R.R., Johnson, R., Poulton, M., Glass, C., Mallon, K., Patil, S.L., Chukwu, G.A., Dandekar, A.Y., Khataniar, S., Ogbe, D.O., and Collett, T.S., 2002, “Resource Characterization and Quantification of Natural Gas-Hydrate and Associated Free-Gas Accumulations in the Prudhoe Bay-Kuparuk River Area on the North Slope of Alaska”, at the SPE-AAPG: Western Region-Pacific Section Conference, Anchorage, Alaska, May 18-23, 2002.

Hunter, R.B., et. al., 2004, Characterization of Alaska North Slope Gas Hydrate Resource Potential, Spring 2004 Fire in the Ice Newsletter, National Energy Technology Laboratory.

Jaiswal, Namit J., 2004, Measurement of gas-water relative permeabilities in hydrate systems, MS Thesis, University of Alaska Fairbanks, 100 p.

Lachenbruch, A.H., Galanis Jr., S.P., and Moses Jr., T.H., 1988 “A Thermal Cross Section for the Permafrost and Hydrate Stability Zones in the Kuparuk and Prudhoe Bay Oil Fields”, Geologic Studies in Alaska by the U.S. Geological Survey during 1987, p. 48-51.

Lee, M.W., 2002, Joint inversion of acoustic and resistivity data for the estimation of gas hydrate concentration: U.S. Geological Survey Bulletin 2190, 11 p.

Lee, M.W., 2004, Elastic velocities of partially gas-saturated unconsolidated sediments, Marine and Petroleum Geology 21, p. 641–650.

Lee, M. W., 2005, Well-log analysis to assist the interpretation of 3-D seismic data at the Milne Point, North Slope of Alaska, U. S. Geological Survey Scientific Investigation Report SIR 2005-5048, 18 p.

Lewis, R.E., Collett, T.S., and Lee, M.W., 2001, Integrated well log montage for the Phillips Alaska Inc., Kuparuk River Unit (Tarn Pool) 2N-349 Well (unpublished administrative report).

Khataniar, S, Kamath, V.A., Omenihu, S.D., Patil, S.L., and Dandekar, A.Y., 2002, “Modeling and Economic Analysis of Gas Production from Hydrates by Depressurization Method”, The Canadian Journal of Chemical Engineering, Volume 80, February 2002.

Werner, M.R., 1987, Tertiary and Upper Cretaceous heavy-oil sands, Kuparuk River Unit area, Alaska North Slope, in Meyer, R.F., ed., Exploration for heavy crude oil and natural bitumen: American Association of Petroleum Geologists Studies in Geology 25, p. 537-547.

Westervelt, Jason V., 2004, Determination of methane hydrate stability zones in the Prudhoe Bay, Kuparuk River, and Milne Point units on the North Slope of Alaska, MS Thesis, University of Alaska Fairbanks, 85 p.

Zhao, B., 2003, Classifying Seismic Attributes in the Milne Point Unit, North Slope of Alaska, MS Thesis, University of Arizona, 159 p.

7.2 University of Arizona Research Publications and Presentations

7.2.1 Professional Presentations

a. Casavant, R.R., Hennes, A.M., Johnson, R., and T.S. Collett, 2004, Structural analysis of a proposed pull-apart basin: Implications for gas hydrate and associated free-gas emplacement, Milne Point Unit, Arctic Alaska, AAPG Hedberg Conference, Gas Hydrates: Energy Resource Potential and Associated Geologic Hazards, September 12-16, 2004, Vancouver, BC, Canada, 5 pp.
b. Hagbo, C. and R. Johnson, 2003, Delineation of gas hydrates, North Slope, Alaska, 2003 Univ. of Arizona Dept. Geosciences Annual GeoDaze Symposium
c. Hagbo, C., and Johnson, R. A., 2003, Use of seismic attributes in identifying and interpreting onshore gas-hydrate occurrences, North Slope, Alaska, Eos Trans. AGU, 84, Fall Meet.
d. Hennes, A., and R. Johnson, 2004, Structural character and constraints on a shallow, gas-hydrate-bearing reservoir as determined from 3-D seismic data, North Slope, Alaska, 2004 Univ. of Arizona Dept. Geosciences Annual GeoDaze Symposium.

7.2.2 Professional Posters

a. Poulton, M.M., Casavant, R.R., Glass, C.E., and B. Zhao, 2004, Model Testing of Methane Hydrate Formation on the North Slope of Alaska With Artificial Neural Networks, AAPG Hedberg Conference, Gas Hydrates: Energy Resource Potential and Associated Geologic Hazards, September 12-16, 2004, Vancouver, BC, Canada, 2 pp.
b. Geauner, S., Manuel, J., and R.R. Casavant, 2004, Well Log Normalization and Comparative Volumetric Analysis of Gas Hydrate and Free-Gas Resources, Central North Slope, Alaska, AAPG Hedberg Conference, Gas Hydrates: Energy Resource Potential and Associated Geologic Hazards, September 12-16, 2004, Vancouver, BC, Canada, 4 pp.
c. Gandler, G.L., Casavant, R.R., Johnson, R.A., Glass, K, and T.S.Collett, 2004, Preliminary Spatial Analysis of Faulting and Gas Hydrates-Free Gas Occurrence, Milne Point Unit, Arctic Alaska, AAPG Hedberg Conference, Gas Hydrates: Energy Resource Potential and Associated Geologic Hazards, September 12-16, 2004, Vancouver, BC, Canada, 3 pp.
d. Hennes, M., Johnson, R.A., and R.R. Casavant, 2004, Seismic Characterization of a Shallow Gas-Hydrate-Bearing Reservoir on the North Slope of Alaska, AAPG Hedberg Conference, Gas Hydrates: Energy Resource Potential and Associated Geologic Hazards, September 12-16, 2004, Vancouver, BC, Canada, 4 pp.

e. Hennes, A., and R. Johnson, 2004, Pushing the envelope of seismic data resolution: Characterizing a shallow gas-hydrate reservoir on the North Slope of Alaska, 2004 Univ. of Arizona Dept. Geosciences Annual GeoDaze Symposium.
f. Geauner, J.M., Manuel, J., And Casavant, R.R., 2003, Preliminary Subsurface Characterization And Modeling Of Gas Hydrate Resources, North Slope, Alaska, in: Student Abstract Volume, 2003 AAPG-SEG Student Expo, Houston, Texas.

7.2.3 Professional Publications

a. Poulton, M.M., Casavant, R.R., Glass, C.E., and B. Zhao, 2004, Model Testing of Methane Hydrate Formation on the North Slope of Alaska With Artificial Neural Networks, AAPG Hedberg Conference, Gas Hydrates: Energy Resource Potential and Associated Geologic Hazards, September 12-16, 2004, Vancouver, BC, Canada, 2 pp.
b. Geauner, S., Manuel, J., and R.R. Casavant, 2004, Well Log Normalization and Comparative Volumetric Analysis of Gas Hydrate and Free-Gas Resources, Central North Slope, Alaska, AAPG Hedberg Conference, Gas Hydrates: Energy Resource Potential and Associated Geologic Hazards, September 12-16, 2004, Vancouver, BC, Canada, 4 pp.
c. Gandler, G.L., Casavant, R.R., Johnson, R.A., Glass, K, And T.S.Collett, 2004, Preliminary Spatial Analysis Of Faulting And Gas Hydrates-Free Gas Occurrence, Milne Point Unit, Arctic Alaska, AAPG Hedberg Conference, Gas Hydrates: Energy Resource Potential And Associated Geologic Hazards, September 12-16, 2004, Vancouver, BC, Canada, 3 pp.
d. Hennes, M., Johnson, R.A., And R.R. Casavant, 2004, Seismic Characterization Of A Shallow Gas-Hydrate-Bearing Reservoirs On The North Slope Of Alaska, AAPG Hedberg Conference, Gas Hydrates: Energy Resource Potential And Associated Geologic Hazards, September 12-16, 2004, Vancouver, BC, Canada, 4 pp.
e. Johnson, R. A., 2003, Shallow Natural-Gas Hydrates Beneath Permafrost: A Geophysical Challenge To Understand An Unconventional Energy Resource, News From Geosciences, Department Of Geosciences Newsletter, V. 8, No. 2, p. 4-6.
f. Hagbo, C., And Johnson, R. A., 2003, Use Of Seismic Attributes In Identifying And Interpreting Onshore Gas-Hydrate Occurrences, North Slope, Alaska, EOS Trans. AGU, 84, Fall Meet. Suppl., Abstract OS42B-06.
g. Geauner, J.M., Manuel, J., And Casavant, R.R., 2003, Preliminary Subsurface Characterization And Modeling Of Gas Hydrate Resources, North Slope, Alaska; in: Student Abstract Volume, 2003 AAPG-SEG Student Expo, Houston, Texas.
h. Hennes, A., and R. Johnson, 2004, Structural character and constraints on a shallow, gas-hydrate-bearing reservoir as determined from 3-D seismic data, North Slope, Alaska, 2004 Univ. of Arizona Dept. Geosciences Annual GeoDaze Symposium.
i. Hennes, A., and R. Johnson, 2004, Pushing the envelope of seismic data resolution: Characterizing a shallow gas-hydrate reservoir on the North Slope of Alaska, 2004 Univ. of Arizona Dept. Geosciences Annual GeoDaze Symposium.

j. Hagbo, C. and R. Johnson, 2003, Delineation of gas hydrates, North Slope, Alaska, 2003 Univ. of Arizona Dept. Geosciences Annual GeoDaze Symposium.
k. Geauner, J.M., Manuel, J., and Casavant, R.R., 2003, Preliminary subsurface characterization and modeling of gas hydrate resources, North Slope, Alaska; in: Student Abstract Volume, 2003 AAPG-SEG Student Expo, Houston, Texas.
l. Casavant, R. R., 2002, Tectonic geomorphic characterization of a transcurrent fault zone, Western Brooks Range, Alaska (linkage of shallow hydrocarbons with basement deformation), SPE-AAPG: Western Region-Pacific Section Joint Technical Conference Proceedings, Anchorage, Alaska, May 18-23, 2002, p. 68.

7.2.4 Sponsored Thesis Publications

a. Hennes, A.M., 2004, Structural Constraints on Gas-hydrate Formation and Distribution in the Milne Point, North Slope of Alaska, M.S. Thesis (Prepublication Manuscript), Dept. of Geosciences, University of Arizona, Tucson, 76 pp.
b. Hagbo, C.L., 2003, Characterization of Gas-hydrate Occurrences using 3D Seismic Data and Seismic Attributes, Milne Point, North Slope, Alaska, M.S. Thesis, Dept. of Geosciences, University of Alaska, Tucson, 127 pp.
c. Zhoa, Bo, 2003, Classifying Seismic Attributes in the Milne Point Unit, North Slope of Alaska, M.S. Thesis, Dept. of Mining and Geological Engineering, University of Arizona, Tucson, 159 pp.

7.2.5 Artificial Neural Network References

Bishop, C., 1995, Neural Networks for Pattern Recognition: Oxford Press.

Broomhead, D., and Lowe, D., 1988, Multivariable functional interpolation and adaptive networks: Complex Systems, 2, 321-355.

Casavant, R. R., 2001, Morphotectonic Investigation of the Arctic Alaska Terrane: Implications to Basement Architecture, Basin Evolution, Neotectonics and Natural Resource Management: Ph.D thesis, University of Arizona, 457 p.

Casavant, R., Hennes, A., Johnson, R., and Collett, T., 2004, Structural analysis of a proposed pull-apart basin: Implications for gas hydrate and associated free-gas emplacement, Milne Point Unit, Arctic Alaska: AAPG HEDBERG ONFERENCE, "Gas Hydrates: Energy Resource Potential and Associated Geologic Hazards" September 12-16, 2004, Vancouver, BC, Canada.

Collett, T., Bird, K., Kvenvolden, K., and Magoon, L., 1988, Geologic interrelations relative to gas hydrates within the North Slope of Alaska: USGS Open File Report, 88-389.

Darken, C., and Moody, J., 1990, Fast adaptive K-means clustering: Some empirical results: IEEE INNS International Joint Conference on Neural Networks, 233-238.

Gandler, G., Casavant, R., Glass, C., Hennes, A., Hagbo, C., and Johnson, R., 2004, Preliminary Spatial Analysis of Faulting and Gas Hydrate Occurrence Milne Point Unit, Arctic Alaska: AAPG HEDBERG CONFERENCE, "Gas Hydrates: Energy Resource Potential and Associated Geologic Hazards" September 12-16, 2004, Vancouver, BC, Canada.

Geauner, S., Manuel, J., Casavant, R., Glass, C., and Mallon, K., 2004,Well Log Normalization and Comparative Volumetric Analyses of Gas Hydrate and Free-gas Resources, Central North Slope, Alaska: AAPG HEDBERG CONFERENCE, "Gas Hydrates: Energy Resource Potential and Associated Geologic Hazards" September 12-16, 2004, Vancouver, BC, Canada.

Girosi, F. and Poggio, T., 1990, Networks and the best approximation property: Biological Cybernetics, 63, 169-176.

Glass, C. E. 2003, Estimating pore fluid concentrations using acoustic and electrical log attributes, Interim Report, UA Gas Hydrate Project.

Hagbo, C., 2003, Characterization of gas-hydrate occurrences using 3D seismic data and seismic attributes, Milne Point, North Slope, Alaska: MS Thesis, University of Arizona, Tucson, Arizona.

Hashin, Z and S. Shtrikman, 1963, A variational approach to the theory of the elastic behavior of multiphase materials, Journal of the Mechanics and Physics of Solids, Vol. 11, p. 127-140.

Haykin, S., 1994, Neural Networks. A Comprehensive Foundation: Macmillan.
Light,W., 1992, Some aspects of radial basis function approximation, in Singh, S., Ed., Approximation Theory, Spline Functions and Applications: NATO ASI series, 256, Kluwer Academic Publishers, 163-190.

Mavco, G., T. Mukerji and J. Dvorkin, 1988, The rock physics handbook, Cambridge University Press.

Moody, J., and Darken, C., 1989, Fast learning in networks of locally-tuned processing units: Neural Computation, 1, 281-294.

Musavi, M., Ahmed,W., Chan, K., Faris, K., and Hummels, D., 1992, On the training of radial basis function classifiers: Neural Networks, 5, 595-603.

Poggio, T. and Girosi, F., 1989, A theory of networks for approximation and learning: A.I. Memo No. 1140 (C.B.I.P . Paper No. 31), Massachusetts Institute of Technology, Artificial Intelligence Laboratory.

Poulton, M., 2002, Neural networks as an intelligence amplification tool: A review of applications: Geophysics, vol. 67, no. 3, pp. 979-993.

Poulton, M., (Ed.), 2001, Computational Neural Networks for Geophysical Data Processing: Pergamon, Amsterdam, 335p.

Powell, M., 1987, Radial basis functions for multivariable interpolation: A review, in Mason, J. and Cox, M., Eds., Algorithms for Approximation: Clarendon Press.

Zell, A., 1994, Simulation Neuronaler Netze: AddisonWesley.

Zhao, B., 2003, Classifying Seismic Attributes In The Milne Point Unit, North Slope of Alaska: MS Thesis, University of Arizona, Tucson, Arizona.

7.3 Gas Hydrate Phase Behavior and Relative Permeability References

ASTM, 2000, "Standard Test Method for Permeability of Granular Soils (constant head) D 2434-68", American Society for Testing and Materials, Annual Book of ASTM Standards, West Conshohocken, PA, 202-206.

Dvorkin, J., Helgerud, M.B., Waite, W.F., Kirby, S.H. and Nur, A., 2000, "Introduction to Physical Properties and Elasticity Models", in Natural Gas Hydrate in Oceanic and Permafrost Environments, edited by M.D. Max, pp 245-260, Kluwer, Dordrecht.

Gash, B.W., 1991, "Measurement of Rock Properties in Coal for Coalbed Methane Production", Paper 22909 presented at the 1991 SPE annual Technical conference and Exhibition, Dallas, October 6-9.

Johnson, E.F., Bossler, D.P., and Neumann, V.O., 1959, "Calculation of Relative Permeability from Displacement Experiments", Trans. AIME, 216, 370- 372.

Jones, S.C. and Roszelle, W.O., 1978, "Graphical Techniques for Determining Relative Permeability from Displacement Experiments", JPT, (May 1978), 807-817.

Joseph W. W. and Duane H.S., 2002, "Upper Limits on the Rates of Dissociation of Clathrate Hydrates to Ice and Free Gas", J. Phys. Chem. B., (May 2002), 106, 6298-6302.

Makogon, Y.F., Makogon, T.Y. and Holditch, S.A., 1998, "Several Aspects of the Kinetics and Morphology of Gas Hydrates", Proceedings of the International Symposium on Methane Hydrates: Resources in the Near Future?, Chiba City, Japan, 20-22, October 1998.

Masuda, Y., Ando, S., Ysukui, H., and Sato, K., 1997, "Effect of Permeability on Hydrate Decomposition in Porous Media", International Workshop on Gas Hydrate Studies, Tsukuba, Japan, Mar 4-6, 1997.

Mehrad, N., 1989, "Measurement of gas permeability in hydrate saturated unconsolidated cores", M.S thesis, University of Alaska Fairbanks.

Owens, W.W., Parrish, D.R., and Lamoreausx, W.E., 1956, "An Evaluation of Gas Drive Method for Determining Relative Permeability Relationships", Trans., AIME 207, 275-280.

Scheidegger, A.E., 1998, The Physics of Flow Through Porous Media, Macmillan, New York.

Sloan, E.D., 1998, Clathrate Hydrates of Natural Gases, Mercel Dekker, New York.

Spangenberg,W., 2001, “Modeling of the influence of gas hydrate content on the electrical properties of porous sediments”, J of Geophys. Res B., 106, 6535-6549.

Stern, L.A., Kirby, S.H., Durham, W.B., Circone, S. and Waite, W.F., 2000, “ Laboratory synthesis of pure methane hydrate suitable for measurement of physical properties and decomposition behavior” in Natural Gas Hydrate in Oceanic and Permafrost Environments, edited by M.D. Max, pp 323-348, Kluwer, Dordrecht.

Tooth, J., Bodi, T., et al., 2000, “Analytical Techniques for Determination of Relative Permeability from Displacement Experiments”, Progress in Mining and Oilfield Chemistry, Vol-2, 91-100.

Westervelt, J.V., 2004. "Determination of methane hydrate stability zones in the Prudhoe Bay, Kuparuk River, and Milne Point units on the North Slope of Alaska". MS Thesis, University of Alaska Fairbanks, Fairbanks, AK.

Wilder, J.W., Seshadri, K. and Smith, D.H., 2001, “Modeling Hydrate Formation in Media With Broad Pore Size Distributions”, Langmuir 17, 6729-6735.

Winters, W.J., Dillon, W.P., Pecher, I.A. and Mason, D.H., 2000, “GHASTLI-Determining physical properties of sediment containing natural and laboratory formed gas hydrate” in Natural Gas Hydrate in Oceanic and Permafrost Environments, edited by M.D. Max, pp 311-322, Kluwer, Dordrecht.

7.4 Drilling Fluid Evaluation and Formation Damage References

7.4.1.1 Formation Damage Prevention References, In-Review Publication

The following references were used in developing Section 5.7.3 of this report.

1. Collett, T.S.: “Well Log Characterization of Sediments in Gas-Hydrate-Bearing Reservoirs”, SPE 49298, presented at SPE Annual Technical Conference and Exhibition, New Orleans, Louisiana, September 27-30, 1998.

2. Collett, T.S., Bird, K.J., Magoon, L.B.: “Subsurface Temperatures and Geothermal Gradients on the North Slope of Alaska”, SPE 19024, Society of Petroleum Engineers, 1988.

3. Collett, T.S.: “Natural Gas Hydrates of the Prudhoe Bay and Kuparuk River Area North Slope, Alaska”, The American Association of Petroleum Geologists Bulletin, Vol. 77, No. 5, pp. 793-812, May 1993.

4. Dallimore, S.R., Uchida, T., Collett, T.S.: "Scientific Results from JAPEX/JNOC/GSC Mallik 2L-38 Gas Hydrate Research Well, Mackenzie Delta, Northwest Territories, Canada", Geological Survey of Canada Bulletin 544, February 1999.

5. Dvorkin, J., Helgerud, M.B., Waite, W.F., Kirby, S.H., Nur, A., "Introduction to Physical Properties and Elasticity Models, in Natural Gas Hydrate in Oceanic and Permafrost Environments, edited by M.D. Max, pp. 245-260, Kluwer, Dordrecht, 2000.

6. Ginsburg, G., Soloviev, V., Matveeva, T., Andreeva, I.: "Sediment Grain Size Control on Gas Hydrate Presence, Sites 994, 995, and 997", Proceedings of the Ocean Drilling Program, Scientific Results, Leg 164, edited by C.K. Paul et al., chap. 24, Ocean Drilling Program, College Station, Texas, 2000.

7. Kamath, V.A., Patil, S.L.: "Description of Alaskan Gas Hydrate Resources and Current Technology", studies by University of Alaska Fairbanks, January 1994.

8. Kerkar, P.B.: "Assessment of Formation Damage from Drilling Fluids Dynamic Filtration in Gas Hydrate Reservoirs of the North Slope of Alaska", M.S. Thesis, University of Alaska Fairbanks, August 2005.

9. Marshall, D.S., Gray, R., Byrne, M.: "Development of a Recommended Practice for Formation Damage Testing", SPE 38154, presented at the SPE European Formation Damage Conference, Hague, Netherlands, June 2-3, 1997.

10. Matsumoto, R., "Comparison of Marine and Permafrost Gas Hydrates: Examples from Nankai Trough and Mackenzie Delta, Proceedings of the Fourth International Conference on Gas Hydrates, Yokohama, 19-23 May 2002a.

11. Murlidharan, V., Putra, E., Schechter, D.S.: "Investigating the Changes in Matrix and Fracture Properties and Fluid Flow under Different Stress-state Conditions", M.S. Thesis, Texas A & M University, 2002.

12. Shipboard Scientific Party: "Leg 204 Preliminary Report, Drilling Gas Hydrates on Hydrate Ridge, Cascadia Continental Margin", ODP Texas A & M University, December 2002, Available from World Wide Web:
http://www-odp.tamu.edu/publications/prelim/204_prel/204PREL.PDF.

13. Winters, W.J., Dallimore, S.R., et al.: "Physical properties of sediments from the JAPEX/JNOC/GSC Mallik 2L-38 Gas Hydrate Research Well", in Geological Survey of Canada Bulletin 544: Scientific Results from JAPEX/JNOC/GSC Mallik 2L-38 Gas Hydrate Research Well, Mackenzie Delta, Northwest Territories, Canada, edited by Dallimore, S.R. et al. Geological Survey of Canada, Ottawa, 1999.

14. Yousif, M.H., Abass, H.H., Selim, M.S., Sloan, E.D.: "Experimental and Theoretical Investigation of Methane-Gas-Hydrate Dissociation in Porous Media"; SPE 18320, SPE Reservoir Engineering, February 1991.

7.4.1.2 Formation Damage Prevention References, General

Anselme, M.J., Reijnhout, M.J., Muijs, H.M., Klomp, 1993, U.C.; World Pat. WO 93/25798.

Belavadi, M.N., 1994, "Experimental Study of the Parameters Affecting Cutting Transportation in a Vertical Wellbore Annulus"; M.S.Thesis, UAF; Sept., 1994.

Bennion D.B., Thomas F.B., Bietz R.F., 1996, “Low permeability Gas Reservoirs: Problems, Opportunities and Solution for Drilling, Completion, Simulation and Production”; SPE 35577; May 1996.

Bennion D.B., Thomas F.B., Bietz R.F., 1996 “Formation Damage and Horizontal Wells- A Productivity Killer?” SPE 37138; International Conference on Horizontal Well Technology, Calgary; Nov. 1996.

Bennion D.B., Thomas F.B., Bietz R.F., 1995, “Underbalanced Drilling and Formation Damage- Is it a Total Solution?”; The Journal of Canadian Petroleum Tech.; Vol. 34 (9); Nov. 1995.

Bennion D.B., Thomas F.B., et al., 1995, “Advances in Laboratory Core Flow Evaluation to minimize Formation Damage Concerns with Vertical/Horizontal Drilling Application”; CAODC; Vol. 95 (105).

Bennion D.B., Thomas F.B, Jamaluddin, K.M., Ma T.; “Using Underbalanced Drilling to Reduce Invasive Formation Damage and Improve Well Productivity- An Update”; Petroleum Society of CIM; PTS 98-58.

Chadwick J., 1995, “Exploration in permafrost”; Mining Magazine; February, 1995.

Chen, W., Patil S.L., Kamath, V.A., Chukwu, G.A., 1998, “Role of Lecithin in Hydrate Formation/Stabilization in Drilling Fluids”; JNOC; October 20, 1998.

Chilingarian G.V., Vorabutr P., 1983, “Drilling and drilling fluids”; Elsevier; NY.

Cohen J.H., Williams T.E., 2002, “Hydrate Core Drilling Tests: Topical Report”; Maurer Technology Inc., Houston, Texas; November 2002.

Crowell, E.C., Bennion, D.B., Thomas, F.B., Bennion, D.W., 1992, “The Design & Use of Laboratory Tests to Reduce Formation Damage in Oil & Gas Reservoirs”; 13th Annual Conference of the Ontario Petroleum Institute.

Dallimore, S.R., Uchida, T., Collett, T.S., 1999, “Scientific Results from JAPEX/JNOC/GSC Mallik 2L-38 Gas Hydrate Research Well, Mackenzie Delta, Northwest Territories, Canada”; Geological Survey of Canada Bulletin 544; February, 1999.

Drill Cool Systems Canada Inc., www.drillcool.com.

Duncum, S.N., Edwards, A.R., Osborne, C.G., 1993, Eur. Pat. 536,950.

Francis P.A., Eigner M.R.P., et. al.., 1995, "Visualization of Drilling-Induced Formation Damage Mechanisms using Reservoir Conditions Core Flood Testing"; paper SPE 30088 presented at the 1995 European Formation Damage Conference, The Hague, May 15-16.

Fu, S.B., Cenegy, L.M., Neff C.S., 2001, "A Summary of Successful Field Application of A Kinetic Hydrate Inhibitor"; SPE 65022.

Hammerschmidt E.G., 1934, Ind.Eng.Chem.; 26, 851.

Howard S.K., 1995, "Formate Brines for Drilling and Completion: State of the Art"; SPE 30498.

I.F.P. patents: Fr.Pats. 2,625,527; 2,625,547; 2,625,548; 2,694,213; 2,697,264: Eur. Pats. 594,579; 582,507323,775; 323307: US Pat. 5,244,878. Can.Pat. 2,036,084.

Jamaluddin A.K.M., Bennion D.B., et. al.; "Application of Heat Treatment to Enhance Permeability in Tight Gas Reservoirs"; Petroleum Society of CIM; Paper No. 98-01.

Kalogerakis N., Jamaluddin, et. al., 1993, "Effect of Surfactants on Hydrate Formation Kinetics"; SPE 25188.

Kamath V.A., Mutalik P.N., et. al., 1991, "Experimental Study of Brine Injection and Depressurization Methods for Dissociation of Gas Hydrate"; SPE Formation Evaluation; December 1991.

Kastube T.J., Dallimore S.R., et. al., 1999, "Gas Hydrate Investigation in Northern Canada"; JAPEX; Vol. 8; No. 5.

Kelland, M.A., Svartaas, T.M., Dybvik, L.A., 1994, "Control of Hydrate Formation by Surfactants and Polymers"; SPE 28506; p. 431-438.

Kotkoskie T.S., AL-Ubaidi B., et. al., 1990, "Inhibition of Gas Hydrates in Water-Based Drilling Mud"; SPE 20437.

Kutasov I.M., 1995, "Salted drilling mud helps prevent casing collapse in permafrost"; Oil & Gas Journal; July 31, 1995.

Marshal, D.S., Gray, R., Byrne, M.; 1997, "Development of a Recommended Practice for Formation Damage Testing"; SPE 38154; Presented at the 1997 SPE European Formation Damage Conference; Netherlands, 2-3 June 1997.

Maury V., Guenot A., 1995, "Practical Advantages of Mud Cooling Systems for Drilling"; SPE Drilling & Completion, March 1995.

Max M.D., 2000, "Natural Gas Hydrate in Oceanic & Permafrost Environments"; Kluwer Academic Publishers; Boston; 2000.

Muijs, H.M., Beers, N.C., et al., 1990, Can. Pat. 2,036,084.

Oort E.V., Friedheim J.M., Toups B., 1999, "Drilling faster with Water-Base Mud"; American Association of Drilling Engineers – Annual Technical Forum; Texas; March 30-31, 1999.

Paez, J.E., Blok, R., Vaziri, H., Islam M.R., 2001, "Problems in Hydrates: Mechanisms and Elimination Methods"; SPE 67322.

Pooladi-Darvish M., Hong, H., 2003, "A Numerical Study on Gas Production From Formations Containing Gas Hydrates"; Canadian International Petroleum Conference, Calgary, June 10-12, 2003.

Reijnhout, M.J., Kind, C.E., Klomp, 1993, U.C.; Eur. Pat. 526,929.

Robinson L.; 1977, "Mud equipment manual, Handbook 1: Introduction to drilling mud system"; Gulf Publishing Company; Houston.

Sasaki K., Akibayashi S., Konno S., 1998, "Thermal and Rheological properties of Drilling Fluids and an Estimation of Heat Transfer Rate at Casing pipe"; JNOC-TRC, Japan; October 20-22, 1998.

Schofield T.R., Judis A., Yousif M., 1997, "Stabilization of In-Situ Hydrates Enhances Drilling Performance and Rig Safety"; SPE 32568 ; Drilling & Completion.

Sira J.H., Patil S.L., Kamath V.A., 1990, "Study of Hydrate Dissociation by Methanol and Glycol Injection"; SPE 20770.

Sloan, E.D., 1994, World Pat. WO 94/12761.

Spence G.D., Hyndman R.D., 2001, "The challenge of Deep ocean Drilling for Natural Gas Hydrate"; Geoscience Canada; Vol.28 (4); December, 2001.

Sumrow Mike, 2002, "Synthetic-based muds reduce pollution discharge, improve drilling"; Oil & Gas Journal; Dec. 23, 2002.

Szczepanski R., Edmonds B., et. al., 1998, "Research provides clues to hydrate formation and drilling-hazard solutions"; Oil & Gas Journal; Vol. 96(10); Mar 9, 1998.

Toshiharu O., Yuriko M., et. al., 1998, "Kinetic Control of Methane Hydrates in Drilling Fluids"; JNOC-TRC; October 20-22, 1998.

Urdahl, O., Lund, A., Moerk, P., Nilsen, T-N, 1995 "Inhibition of Gas Hydrate Formation by means of Chemical Additives: Development of an Experimental Set-up for Characterization of Gas Hydrate Inhibitor Efficiency with respect to Flow Properties and Deposition"; Chem. Eng. Sci.; 50(5), 863.

Vincent M., Guenot Alain, 1995, “Practical Advantages of Mud Cooling System for Drilling”; SPE Drilling & Completion; March 1995.

Weidong C., Patil S.L., Kamath V.A., Chukwu G.A., 1998, “Role of Lecithin in Hydrate Formation/Stabilization in Drilling Fluids”; JNOC-TRC; October 20-22, 1998.

Yuliev, A.M.; Gazov, Delo, 1972, 10, 17-19, Russ.

Zakharov A.P., 1992, “Silicon-based additives improve mud Rheology”; Oil & Gas Journal; Aug. 10, 1992.

7.5 Coring Technology References

Amann, H. et al., 2002, “First Successful Deep-Sea Operations of OMEGA-MAC, the Multiple Auto Corer, during the OTEGA-I campaign on Hydrate Ridge”. Fachgebiet Maritime Technik. August 2002.

Carroll, John, 2002, “Natural Gas Hydrates: A Guide for Engineers”. Gulf Professional Publishing. October 30, 2002.

Dickens, Gerald R. et al., 2000, “Detection of Methane Gas Hydrate in the Pressure Core Sampler (PCS): Volume-Pressure-Time Relations During Controlled Degassing Experiments”. *Proc. of the Ocean Drilling Program*, Vol. 164.

Francis, T.J.G., 2001, “The HYACINTH project and pressure coring in the Ocean Drilling Program”. Internal Document: Geotek, Ltd. July 2001.

Hohnberg, H.J. et al., 2003, “Pressurized Coring of Near-Surface Gas Hydrate Sediment on Hydrate Ridge: The Multiple Autoclave Corer, and First Results from Pressure Core X-Ray CT Scans”. Geophysical Research Abstracts, Vol. 5. European Geophysical Society.

“HYACE”, 2003, [www] http://www.tu-berlin.de/fb10/MAT/hyace/description/describe.htm. Accessed June 15th, 2003.

“Methane Hydrate Recovery”, JNOC Website. [www] http://www.mh21japan.gr.jp/english/mh/05kussaku.html#e.

“Methane Hydrates: A US Department of Energy Website”. www.fossil.energy.gov

“Natural Gas Demand”. [www] www.naturalgas.org/business/demand.asp.

“Patent No. 6,214,804: The Pressure-Temperature Coring System”. U.S. Patent Office. [www]http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO1&Sect2=HITOFF&d=PALL&p=1&u=/netahtml/srchnum.htm&r=1&f=G&l=50&s1=6,216,804.WKU.&OS=PN/6,216,804&RS=PN/6,216,804. Viewed July 14, 2003.

Rack, Frank R, "In-Situ Sampling and Characterization of Naturally Occurring Marine Hydrate Using the D/V JOIDES Resolution". Joint Oceanographic Institute, Cooperative Agreement DE-FC26-01NT41329.

Shukla, K., et al., 2002, "Overview on Hydrate Coring/Handling/Analysis". Westport Technology Center International. Prepared for DOE on December 12, 2002 under award No. DE-PS26-NT40869-1.

7.6 Reservoir and Economic Modeling References

Brown, G., Storer, D., and McAllister, K., 2003, Monitoring Horizontal Producers and Injectors during Cleanup and Production Using Fiber-Optic-Distributed Temperature Measurements, SPE 84379.

Chuang Ji, Goodarz Ahmadi, Duane H.Smith. 2003; "Constant rate natural gas production from a well in a hydrate reservoir"; Energy Conversion and Management 44, 2403-2423.

Chuang Ji, Goodarz Ahmadi, Duane H. Smith, 2001, "Natural gas production from hydrate decomposition by depressurization"; Chemical eng. science 56, 5801-5814.

Stephen J Howe, 2004, Production modeling and economic evaluation of a potential gas hydrate pilot production program on the north slope of Alaska", MS Thesis, University of Alaska Fairbanks, Fairbanks, AK.

Howe, S.J., Nanchary, N.R., Patil S.L., Ogbe D.O., Chukwu G.A., Hunter R.B and Wilson S.J., "Production Modeling and Economic Evaluation of a Potential Gas Hydrate Pilot Production Program on the North Slope of Alaska", *Manuscript Under Preparation*.

Howe, S.J., Nanchary, N.R., Patil S.L., Ogbe D.O., Chukwu G.A., Hunter R.B and Wilson S.J., "Economic Analysis and Feasibility study of Gas Production from Alaska North Slope Gas Hydrate Resources", Submitted for Presentation at the AAPG Hedberg Conference in Vancouver in September 2004.

Jaiswal N.J presented on "Measurement of Relative Permeabilities for Gas-Hydrate Systems" and received third prize in International Thermal Operations and Heavy-Oil Symposium and SPE Regional Meeting Bakersfield, California, USA.

Jaiswal, N.J., Dandekar, A.Y., Patil, S.L. and Chukwu, G.C., "Measurement of Relative Permeability for Gas-Hydrate System", at 54th Arctic Science Conference, 23rd Sept-2003.

Jaiswal N.J., Westervelt J.V., Patil S.L., Dandekar A.Y., Nanchary, N.R., Tsunemori P and Hunter R.B., "Phase Behavior and Relative Permeability of Gas-Water-Hydrate System", Submitted for Presentation at the AAPG Hedberg Conference in Vancouver in September 2004.

McGuire, P.L., 1982, "Recovery of gas from hydrate deposits using conventional technology," SPE/DOE 10832, *Proc. Unconventional Natural Gas Recovery Symposium Pittsburgh PA*, pp. 373-387, Society of Petroleum Engineers, Richardson Texas.

McGuire, Patrick L., 1982, “Methane hydrate gas production by thermal stimulation”; proceedings of the 4th Canadian Permafrost Conference, pp.356-362.

Moridis, G. J., 2002, “Numerical Studies of Gas Production from Methane Hydrates”. Paper SPE 75691, presented at the SPE Gas Technology Symposium, Calgary, Alberta, Canada, 30 April – 2 May 2002b.

Moridis, G.J. and Collett, T.S., 2004 in-press, “Gas Production from Class 1 Hydrate Accumulations”.

Moridis, G., Collett, T.S., Dallimore, S.R., Satoh, T., Hancock, S. and Weatherill, B., 2003, “Numerical simulation studies of gas production scenarios from hydrate accumulations at the Mallik site, Mackenzie Delta, Canada”. In, Mori, Y.S., Ed. Proceedings of the Fourth International Conference on Gas Hydrates, May 19-23, Yokohama, Japan, pp 239-244.

Nanchary, N.R., Patil S.L., Dandekar A.Y., “Numerical Simulation of Gas Production from Hydrate Reservoirs by Depressurization”, Journal of Petroleum Science & Engineering (Elseveier publication), *Under Review.*

Nanchary, N.R., Patil S.L., Dandekar A.Y and Hunter, R.B., “Numerical Modeling of Gas Hydrate Dissociation in Porous Media”, Submitted for Presentation at the AAPG Hedberg Conference in Vancouver in September 2004.

Swinkles, W.J.A.M. and Drenth, R.J.J., 1999, “Thermal Reservoir Stimulation Model of Prediction from Naturally Occurring Gas Hydrate Accumulations”, Society of Petroleum Engineers, SPE 56550, 13 p.

Tsunemori, Phillip, 2003, presented “Phase Behavior of Natural Gas from Gas Hydrates” and received first in International Thermal Operations and Heavy-Oil Symposium and SPE Regional Meeting Bakersfield, California, USA.

Tsypkin, G.G. 1992, Appearance of two moving phase transition boundaries in the dissociation of gas hydrates in strata. Dokl. Ross. Akad. Nauk. 323. 52-57 (in Russian).

Yousif, M., H., Abass H., H., Selim, M., S., Sloan E.D., 1991, Experimental and Theoretical Investigation of Methane-Gas-Hydrate Dissociation in Porous Media, SPE Res. Eng. 18320, pages 69-76.

Tsypkin, G.G. 1991, Effect of liquid phase mobility on gas hydrate dissociation in reservoirs. Izvestiya Akad. Nauk SSSR. Mekh. Zhidkosti i Gaza. 4: 105-114 (in Russian).
Westervelt J.V: MS Thesis: “Determination of methane hydrate stability zones in the Prudhoe Bay, Kuparuk River, and Milne Point units on the North Slope of Alaska”.

7.7 Regional Schematic Modeling Scenario Study References

Collett, Timothy S.: "Natural Gas Hydrates of the Prudhoe Bay and Kuparuk River Area, North Slope, Alaska," AAPG Bulletin, Vol. 77, No. 5, May, 1993, p 793-812.

S. J. Howe, N. R. Nanchary, S. L. Patil, D. O. Ogbe, and G. A. Chukwu, R. B. Hunter, S. J. Wilson. "Economic Analysis and Feasibility Study of Gas Production from Alaska North Slope Gas Hydrate Resources," AAPG Hedberg Conference, September, 2004.

S.H. Hancock, T.S. Collett, S.R. Dallimore, T. Satoh, T. Inoue, E. Huenges, J. Henninges, and B. Weatherill: "Overview of thermal-stimulation production-test results for the JAPEX/JNOC/GSC et al. Mallik 5L-38 gas hydrate production research well" 2004.

Richard Sturgeon-Berg, "Permeability Reduction Effects Due to Methane and Natural Gas Flow through Wet Porous Media," Colorado School of Mines, MS thesis T- 4920, 9/30/96.

Stephen John Howe, "PRODUCTION MODELING AND ECONOMIC EVALUATION OF A METHANE HYDRATE PILOT PRODUCTION PROGRAM ON THE NORTH SLOPE OFALASKA," University of Alaska, Fairbanks MS Thesis, May, 2004.

Hong H., Pooladi-Darvish, M., and Bishnoi, P. R.:Analytical Modeling of Gas Production from Hydrates in Porous Media," *Journal of Canadian Petroleum Technology (JCPT)* November 2003, Vol. 42 (11) p. 45-56.

7.8 Short Courses

"Natural Gas Hydrates", By Tim Collett (USGS) and Shirish Patil (UAF), A Short Course at the SPE-AAPG: Western Region-Pacific Section Conference, Anchorage, Alaska, May 18-23, 2002, Sponsored by Alaska Division of Geological and Geophysical Surveys and West Coast Petroleum Technology Transfer Council, Anchorage, Alaska.

8.0 LIST OF ACRONYMS AND ABBREVIATIONS

Acronym	Denotation
2D	Two Dimensional (seismic or reservoir data)
3D	Three Dimensional (seismic or reservoir data)
AAPG	American Association of Petroleum Geologists
AAT	Alaska Arctic Terrane (plate tectonics)
AETDL	Alaska Energy Technology Development Laboratory
ADEC	Alaska Department of Environmental Conservation
ANL	Argonne National Laboratory
ANN	Artificial Neural Network
ANS	Alaska North Slope
AOGCC	Alaska Oil and Gas Conservation Commission
AOI	Area of Interest
AVO	Amplitude versus Offset (seismic data analysis technique)
ASTM	American Society for Testing and Materials
BGHSZ	Base of Gas Hydrate Stability Zone
BIBPF	Base of Ice-Bearing Permafrost

BLM	U.S. Bureau of Land Management
BMSL	Base Mean Sea Level
BP	BP or BPXA
BPXA	BP Exploration (Alaska), Inc.
CMR	Combinable Magnetic Resonance log (wireline logging tool – see also NMR)
DOI	U.S. Department of Interior
DGGS	Alaska Division of Geological and Geophysical Surveys
DNR	Alaska Department of Natural Resources
EM	Electromagnetic (referencing potential in-situ thermal stimulation technology)
ERD	Extended Reach Drilling (commonly horizontal and/or multilateral drilling)
FEL	Front-End Loading, reference to effective pre-project operations planning
FG	Free Gas (commonly referenced in association with and below gas hydrate)
GEOS	UA Department of Geology and Geophysics
GH	Gas Hydrate
GOM	Gulf of Mexico (typically referring to Chevron Gas Hydrate project JIP)
GR	Gamma Ray (well log)
GTL	Gas to Liquid
GSA	Geophysical Society of Alaska
HP	Hewlett Packard
JBN	Johnson-Bossler-Naumann method (of gas-water relative permeabilities)
JIP	Joint Industry Participating (group/agreement), ex. Chevron GOM project
JNOC	Japan National Oil Corporation
JOGMEC	Japan Oil, Gas, and Metals National Corporation (reorganized from JNOC 1/04)
KRU	Kuparuk River Unit
LBNL	Lawrence Berkeley National Laboratory
LDD	Generic term referencing Logging During Drilling (also LWD and MWD)
LNG	Liquefied Natural Gas
MGE	UA Department of Mining and Geological Engineering
MPU	Milne Point Unit
MSFL	Micro-spherically focused log (wireline log indication of formation permeability)
NETL	National Energy Technology Laboratory
NMR	Natural Magnetic Resonance (wireline or LDD tool – see also CMR)
ONGC	Oil and Natural Gas Corporation Limited (India)
PBU	Prudhoe Bay Unit
PNNL	Pacific Northwest National Laboratory
Sag	Sagavanirktok formation
SPE	Society of Petroleum Engineers
TCF	Trillion Cubic Feet of Gas at Standard Conditions
TCM	Trillion Cubic Meters of Gas at Standard Conditions
T-D	Time-Depth (referencing time to depth conversion of seismic data)
UA	University of Arizona (or Arizona Board of Regents)
UAF	University of Alaska, Fairbanks
USGS	United States Geological Survey
USDOE	United States Department of Energy
Vp	Velocity of primary seismic wave component
Vs	Velocity of shear seismic wave component (commonly useful to identify GH)

	(also component in Di-pole sonic logging tool)
VSP	Vertical Seismic Profile
WOO	Well-of-Opportunity

9.0 APPENDICES

9.1 APPENDIX A: Project Task Schedules and Milestones

9.1.1 U.S. Department of Energy Milestone Log, Phase 1, 2002-2004

Note that SOPO in contract amendments 1-8 for Phase 1.

Program/Project Title: DE-FC26-01NT41332: Resource Characterization and Quantification of Natural Gas-Hydrate and Associated Free-Gas Accumulations in the Prudhoe Bay - Kuparuk River Area on the North Slope of Alaska.

Identification Number	Description	Planned Completion Date	Actual Completion Date	Comments
Task 1.0	Research Management Plan	12/02 – 12/04	12/02 and Ongoing	Subcontracts Completed Research Management
Task 2.0	Provide Technical Data and Expertise	MPU: 12/02 PBU: * KRU: *	MPU: 12/02 PBU: * KRU: *	Ongoing, See Technical Progress Report
Task 3.0	Wells of Opportunity Data Acquisition	Ongoing	Ongoing	Ongoing, See Technical Progress Report
Task 4.0	Research Collaboration Link	Ongoing	Ongoing	Ongoing, See Technical Progress Report
Subtask 4.1	Research Continuity	Ongoing	Ongoing	
Task 5.0	Logging and Seismic Technology Advances	Ongoing		Ongoing, See Technical Progress Report
Task 6.0	Reservoir and Fluids Characterization Study	12/04	Ongoing to Phases 2 and 3	Interim Results presented, 2004 Hedberg Conference
Subtask 6.1	Characterization and Visualization	12/04	Ongoing to Phases 2 and 3	Interim Results presented, 2004 Hedberg Conference
Subtask 6.2	Seismic Attributes and Calibration	12/04	Ongoing to Phases 2 and 3	Interim Results presented, 2004 Hedberg Conference
Subtask 6.3	Petrophysics and Artificial Neural Net	12/04	Ongoing to Phases 2 and 3	Interim Results presented, 2004 Hedberg Conference
Task 7.0	Laboratory Studies for Drilling, Completion, Production Support	6/04	6/04	
Subtask 7.1	Characterize Gas Hydrate Equilibrium	6/04	6/04	Results presented, 2004 Hedberg Conference
Subtask 7.2	Measure Gas-Water Relative Permeabilities	6/04	6/04	Results presented, 2004 Hedberg Conference
Task 8.0	Evaluate Drilling Fluids	12/04		
Subtask 8.1	Design Mud System	11/03		
Subtask 8.2	Assess Formation Damage	9/05	Into Phase 2	

Task 9.0	Design Cement Program	12/04		
Task 10.0	Study Coring Technology	2/04	2/04	
Task 11.0	Reservoir Modeling	12/04	Ongoing task	Interim Results presented, 2004 Hedberg Conference
Task 12.0	Select Drilling Location and Candidate	9/05		Topical Report submitted, June 2005
Task 13.0	Project Commerciality & Phase 2 Progression Assessment	9/05	Redesigned 2005 Phase 2	BPXA and DOE decision

* Date dependent upon industry partner agreement for seismic data release

9.1.2 U.S. Department of Energy Milestone Log, Phase 2, 2006

Note that SOPO in contract amendment 9 for Phase 2.

Program/Project Title: DE-FC26-01NT41332: Resource Characterization and Quantification of Natural Gas-Hydrate and Associated Free-Gas Accumulations in the Prudhoe Bay - Kuparuk River Area on the North Slope of Alaska.

Identification Number	Description	Planned Completion Date	Actual Completion Date	Comments
Task 1.0	Research Management Plan	1/05 – 1/06	Ongoing	Subcontracts Completed Research Management
Task 2.0	Provide Technical Data and Expertise	MPU: 12/02 PBU: * KRU: *	MPU: 12/02 PBU: * KRU: *	Ongoing, See Technical Progress Report; Industry Support more feasible?
Task 3.0	Wells of Opportunity Data Acquisition	Ongoing	Ongoing	Ongoing, See Technical Progress Report
Task 4.0	Research Collaboration Link	Ongoing	Ongoing	Ongoing, See Technical Progress Report
Subtask 4.1	Research Continuity	Ongoing	Ongoing	
Task 5.0	Logging and Seismic Technology Development and Advances	Ongoing		Ongoing, See Technical Progress/Topical reports
Task 6.0	Reservoir and Fluids Characterization Study	12/06	Ongoing into Phases 2 and 3	
Subtask 6.1	Structural Characterization	12/06	Ongoing into Phases 2 and 3	
Subtask 6.2	Resource Visualization	12/06	Ongoing into Phases 2 and 3	
Subtask 6.3	Stratigraphic Reservoir Model	12/06	Ongoing into Phases 2 and 3	
Task 7.0	Laboratory Studies for Drilling, Completion, Production Support	12/06		Some Hiatus; Phase 2-3a design, studies, & decision
Subtask 7.1	Design Mud System	12/05		
Subtask 7.2	Assess Formation Damage	1/06		

Subtask 7.3	Measure Petrophysical and Other Physical Properties	9/06	Phase 3a	No Samples Acquired; await Phase 3a acquisition
Task 8.0	Design Completion / Production Test for Gas Hydrate Well	4/06	Mt Elbert-01 strat test only	Design of Phase 3a Strat Test operation Complete
Task 9.0	Field Operations and Data Acquisition Program Planning	4/06	Mt Elbert-01 strat test only	Planning for Potential operations underway
Task 10.0	Reservoir Modeling and Project Commercial Evaluation	1/06		Regional Resource Review & Development Planning
Subtask 10.1	Task 5-6 Reservoir models	Ongoing		
Subtask 10.2	Hydrate Production Feasibility	1/06		
Subtask 10.3	Project Commerciality & Phase 3a Progression Assessment	1/06		January 2006 approval for Phase 3a Stratigraphic Test

* Date dependent upon industry partner agreement for seismic data release

9.1.3 U.S. Department of Energy Milestone Log, Phase 3a, 2006-2007

Note that SOPO in contract amendment 11 for Phase 3a.

Program/Project Title: DE-FC26-01NT41332: Resource Characterization and Quantification of Natural Gas-Hydrate and Associated Free-Gas Accumulations in the Prudhoe Bay - Kuparuk River Area on the North Slope of Alaska

Identification Number	Description	Planned Completion Date	Actual Completion Date	Comments
Task 1.0	Research Management Plan	1/06 – 12/07	Ongoing	Subcontracts Completed Research Management
Task 2.0	Provide Technical Data and Expertise	MPU: 12/02 PBU: * KRU: *	MPU: 12/02 PBU: * KRU: *	Ongoing, See Technical Progress Report; Industry Support more feasible?
Task 3.0	Wells of Opportunity Data Acquisition	Ongoing	As-identified	Ongoing, See Technical Progress Report
Task 4.0	Research Collaboration Link	Ongoing	Ongoing	Ongoing, See Technical Progress Report
Subtask 4.1	Research Continuity	Ongoing	Ongoing	
Task 5.0	Logging and Seismic Technology Development and Advances	Ongoing	As-needed	Ongoing, See Technical Progress/Topical reports
Task 6.0	Reservoir and Fluids Characterization Study	12/07		Evaluating extension into 2007 for defined scope
Subtask 6.1	Structural Characterization	12/07		Current contract to 12/06
Subtask 6.2	Resource Visualization	12/07		
Subtask 6.3	Stratigraphic Reservoir Model	12/07		
Task 7.0	Laboratory Studies for Drilling, Completion, Production Support	12/07		Evaluating extension into 2007 for defined scope
Subtask 7.1	Design Mud System	9/07		Current contract to 12/06
Subtask 7.2	Assess Formation Damage	9/07		
Subtask 7.3	Measure Petrophysical and Other Physical Properties	9/07		

Task 8.0	Implement completion/production Test for gas hydrate well	3/07		Stratigraphic Test on 2007 Drilling Schedule
Task 9.0	Reservoir Modeling and Project Commercial Evaluation	12/07	Ongoing	Regional Resource Review & Development Planning
Subtask 9.1	Task 5-6 Reservoir models	12/07	As-needed	
Subtask 9.2	Project Commerciality & Phase 3b Production Test Decision	12/07	Early decision possible	Phase 3a Stratigraphic Test to mitigate uncertainties

* Date dependent upon industry partner agreement for seismic data release

9.1.4 U.S. Department of Energy Milestone Plans

(DOE F4600.3)

DOE F 4600.3#

U.S. DEPARTMENT OF ENERGY FEDERAL ASSISTANCE MILESTONE PLAN: PHASE 1

1. Program/Project Identification No. DE-FC26-01NT41332	2. Program/Project Title Resource Characterization and Quantification of Natural Gas-Hydrate and Associated Free-Gas Accumulations in the Prudhoe Bay - Kuparuk River Area on the North Slope of Alaska
3. Performer (Name, Address) BP Exploration (Alaska), Inc., 900 East Benson Blvd, P.O. Box 196612, Anchorage, Alaska 99519-6612	4. Program/Project Start Date 10/22/02* 5. Program/Project Completion Date 12/31/07 (through Phase 3a)

6. Identification Number	7. Planning Category (Work Breakdown Structure Tasks)	8. Program/Project Duration (Currently illustrates 2002-2004)	9. Comments (Primary work Performer)
		O N D J F M A M J J A S O N D J F M A M J J A S-D	
Task 1.0	Research Management Plan	>>!>	BPXA
Task 2.0	Technical Data and Expertise	>>>>>>----->>>>------>>>>>>>>------------>>>>>>>>-------->>>>>>>>-->>>>>>>>--!-	BPXA
Task 3.0	Wells of Opportunity - Data	------>>>>>-------------->>>>>--------->>>>>>>>>>>>>>>---------->>>>>>>>>>>>>>>!-	BPXA
Task 4.0	Research Collaboration Link	>>>!>	BPXA, USGS, UAF, UA
Task 5.0	Logging/Seismic Technology	>>!	USGS, BPXA
Task 6.0	Characterize Reservoir/Fluid	------->>!>>	UA
Task 7.0	Lab Studies: Ph Behav, Rel k	-- ----->>!----------	UAF
Task 8.0	Evaluate Drilling Fluids	------->>>>>>>>>>>>>>>>>>>>>>>>>>>>>>--->>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>	UAF
Task 9.0	Design Cementing Program	------->>>>>>>>>>>>>>>>>>>>>>>>>>>>	UAF
Task 10.0	Study Coring Techniques	-------->>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>- --	UAF
Task 11.0	Reservoir Modeling	>>>>------------------------>>>>>>>>>----------------->>>>>>>>>>>>>>>>>>>>>>>!>>>	UAF, RyderScott
Task 12.0	Drilling Candidate Selection	>>>------ ----->>>>>>------->>>>>>>>>>>>---->>>>>>>>>>>>!	BPXA, UA, USGS, RyderScott
Task 13.0	Commerciality Assessment	>>>>>>-------------------------------->>>>>>>>-------------->>>>>>>----->>>>>>>>>	BPXA, UAF, Ryder Scott

10. Remarks * Official Contract Date 10/22/02; Funded reduced-cost pre-Phase 1 from 10/01-10/02. Phase 1 project from 10/02 through 12/04.
Explanation of Symbols: (> = Major Task Work); (- = Minor Task Work); (! = Milestones).
Additional significant milestones presented in Quarterly Technical Progress Reports.

DOE F 4600.3#

U.S. DEPARTMENT OF ENERGY FEDERAL ASSISTANCE MILESTONE PLAN: PHASE 2-3a (2005-2006)

1. Program/Project Identification No. DE-FC26-01NT41332	2. Program/Project Title Resource Characterization and Quantification of Natural Gas-Hydrate and Associated Free-Gas Accumulations in the Prudhoe Bay - Kuparuk River Area on the North Slope of Alaska
3. Performer (Name, Address) BP Exploration (Alaska), Inc., 900 East Benson Blvd, P.O. Box 196612, Anchorage, Alaska 99519-6612	4. Program/Project Start Date 10/22/02* 5. Program/Project Completion Date 12/31/07 (through Phase 3a)

6. Identification Task Number	7. Planning Category (Work Breakdown Structure Tasks)	8. Program/Project Duration (Currently illustrates Phases 2-3, 2005 - 2006) ← Planning/Analysis → ← DECISION---→ ←Planning--------→← IMPLEMENTATION ………early 2007→ J F M A M J J A S O N D J F M A M J J A S O N D	9. Comments (Primary work Performer)
Task 1.0	Contracts and Research Management Planning	>>>>>>>!>>>--->>>>>!-->>>>>>>>>>>>>>>>>>!---------------------->>---->>-->>>>>>>	BPXA, AES
Task 2.0	Technical Data and Expertise	-->>>>>>----->>>>--!---->>>>>>>>>-------!--->>>>>>>>-------->>>>>>>>-->>>>>>>>--	BPXA, AES
Task 3.0	Wells of Opportunity - Data	------------->>>>>-!------------>>>>>---!----->>>>>>>>>>>>>>>----------->>>>>>>>	BPXA, AES
Task 4.0	Research Collaboration Link	---------->>>>>>>>>!---------->>>>>>>>>>!>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>	BPXA, USGS, AES, UAF,UA
Task 5.0	Logging/Seismic Technology	>>>>>>>>>>>>>>>>>>>!>>>>>>>>>>>>>>>>>>>>!>>>>>>>>>---------------------------->>	USGS, BPXA
Task 6.0	Characterize Reservoir/Fluid	------->>>>>>>>>>>>!---------->>>>>>>>>>!>>>>>>>>>>>>>>>>---------->>>>>>>>>>>>>	UA, USGS
Task 7.0**	Lab Studies: Drilling, Completion, Production	------------>>>>>>>!---------->>>>>>>>>>!>>>>>>>----------------->----->>>>>>>>>	UAF
Task 8.0**	Stratigraphic Test Decision, Design, and Implementation	-->>>>>>>>>>>!>>>----->>>>>>>>>>>>!>>>>>>>--------------------->>>>>>>>>>>	APA, BPXA, AES, UAF
Task 9.0**	Field Operations Planning and Implementation	---->>>>>>>>>!>>>------->>>>>>>>>>!>>>>>>>--------------------->>>>>>>>>>>	APA, BPXA, AES, UAF
Task 10.0**	Reservoir Modeling and Commercial Evaluation	----->>>>>>>>>>>>>>!>>>>>>>>>>>>>>>>>---!---------------------------------------	RS, AES, BPXA, UAF

10. Remarks * Schedule shows Phases 2-3a from 2005 through end-2006. Phase 2 project from 1/05 through 12/05. Phase 3a stratigraphic test initiated 6/05 and included 9/05 Continuation Application culminating in 1/06 decision to Drill. . Explanation of Symbols: >> Major Task Work; -- Minor Task Work; ! Milestone. Significant technical work and milestones presented in Technical Progress and Topical Reports. **Note new (Phase 2-3a) Task numbers.

DOE F 4600.3#

U.S. DEPARTMENT OF ENERGY FEDERAL ASSISTANCE MILESTONE PLAN: PHASE 3a and 3b

1. Program/Project Identification No. DE-FC26-01NT41332	2. Program/Project Title Resource Characterization and Quantification of Natural Gas-Hydrate and Associated Free-Gas Accumulations in the Prudhoe Bay - Kuparuk River Area on the North Slope of Alaska
3. Performer (Name, Address) BP Exploration (Alaska), Inc., 900 East Benson Blvd, P.O. Box 196612, Anchorage, Alaska 99519-6612	4. Program/Project Start Date 10/22/02* 5. Program/Project Completion Date 12/31/07 (through Phase 3a)

6. Identification Task Number	7. Planning Category (Work Breakdown Structure Tasks)	8. Program/Project Duration (Currently illustrates Phases 3a-3b, 2007-2008 projection) ←Phase 3a Strat Test→ ←3b DECISION→←3b Planning→←POTENTIAL PHASE 3b IMPLEMENTATION→ J F M A M J J A S O N D J F M A M J J A S O N D	9. Comments (Primary work Performer)
Task 1.0	Contracts and Research Management Planning	!>>>>>>!>>>--->>>>>!-->>>>>>>>>>!>>>>>>>>---------------------------->>!>>>>>>>>	BPXA, AES
Task 2.0	Technical Data and Expertise	!->>>>>>----->>>>--!---->>>>>>>>!----------->>>>>>>>-------->>>>>>>>-->!>>>>>>--	BPXA, AES
Task 3.0	Wells of Opportunity - Data	!------------>>>>>-!------------!>>>>--------->>>>>>>>>>>>>>>----------!>>>>>>>>	BPXA, AES
Task 4.0	Research Collaboration Link	!>>>>>>>>>>>>>>>>>>!---------->>!>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>!>>>>>>>>	BPXA, USGS, AES, UAF,UA
Task 5.0	Logging/Seismic Technology	!>>>>>>>>>>>>>>>>>>!>>>>>>>>>>>>!>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>!>>>>>>>>	USGS, BPXA
Task 6.0	Characterize Reservoir/Fluid	!------>>>>>>>>>>>>!---------->>!>>>>>>>>>>>>>>>>>>>>>>>---------->>>>>!>>>>>>>>	UA, USGS
Task 7.0	Lab Studies: Drilling, Completion, Production	!----------->>>>>>>!---------->>!>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>!>>>>>>>>	UAF
Task 8.0	Implement 2007 Strat Test Evaluate/Design Production Test & Phase 3b progression	! -->>>>>>>>>>>!>>>----->>>>!>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>!>>>>>>>>	APA, BPXA, AES, UAF
Task 9.0	Reservoir Modeling and Commercial Evaluation	!---->>>>>>>>>>>>>>!>>>>>>>>>>>>!>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>!>>>>>>>>	RS, AES, BPXA, UAF

10. Remarks * Schedule shows Phases 3a-3b (3b not approved-indicated in red) from 2007 projected through end-2008. Phase 3a stratigraphic test deferred until early 2007 by 3rd party rig delay. Explanation of Symbols: >> Major Task Work; -- Minor Task Work; ! Milestone. Significant technical work and milestones presented in Technical Progress and Topical Reports.

9.2 APPENDIX B: Detailed Core Procedure Documentation (Full Text and Figures)

9.2.1 INTRODUCTION

This core procedure document contains a description of BP current best practice for use during core operations (wireline coring, core processing, onsite subsampling, core preservation, transportation, and storage) for the Milne Point Unit (MPU) MtElbert-01 well. This well is being drilled as a Stratigraphic Test within Phase 3a of the BPXA-US Department of Energy (DOE) Gas Hydrate Cooperative Research Project. The core program is one written element of the coring planning this well; others include the pre-coring equipment-supplies checklist, roster, pre-coring risk register assessment, and onsite subsampling procedure station checklist logs. Lessons learned from previous gas hydrate-bearing cored wells, such as the Mallik 1998 and 2002 onshore and certain offshore research programs are fully documented elsewhere, but incorporated into this document where applicable.

The program has been designed to deliver the key core objectives identified by the Gas Hydrate project research team, the MPU development team, and BP Major Projects Common process consultants; it will be reviewed and refined through a number of meetings leading up to well spud, and will be used as an onsite process guideline for Job Risk Assessment (JRA) and dry-run pre-operations onsite training prior to and during the planned wireline coring operations on the Doyon14 rig during the Stratigraphic Test planned in early February 2007.

MtElbert-01 is the first of three planned appraisal wells to be drilled in MPU during the 2007 ice-pad exploration season. One of the primary objectives of this well is to obtain approximately 400 to 600 feet of low invasion 3 inch whole wireline-retrievable core from the gas hydrate-bearing Sagavanirktok reservoirs present beneath the Permafrost within the Eileen gas hydrate trend (Figures 1 and 2) to improve reservoir characterization and resource determination. This program will also acquire the first wireline core on the Alaska North Slope using an improved version of the ReedHycalog (Corion) Wireline Express tool that successfully retrieved, via wireline, the inner core barrel through the drill string in the Mallik 2002 gas hydrate project. This coring protocol document gives the technical justifications and methods for acquiring, subsampling, transporting, and storing this core to meet the project objectives.

9.2.1.1 Project Justification

The U.S. Department of Energy (DOE) has awarded BPXA an additional $4,854,247 through up to end-2007 in contract amendments 11-16 to drill a Stratigraphic test and acquire data within Phase 3a of the Gas Hydrate Cooperative Research Agreement (CRA). Phase 3a was approved January 16, 2006 as a continuation of the gas hydrate research initially contracted with DOE October 22, 2002. Phases 1 and 2 were completed by end-2005.

The CRA Phase 3a will provide further information regarding gas hydrate resource potential while building and maintaining BP reputational and DOE relationship benefits. Direct impacts to BP staff would remain minimized through retaining key team researchers at universities, government agencies, and consulting companies.

Phase 1-2 CRA results suggest 0-12 TCF could be recovered from 33 TCF in-place within shallow MPU/PBU/KRU gas hydrate reservoirs. The planned core and log data acquisition should help narrow the range of this recoverable resource uncertainty. Gas hydrate production would yield methane and fresh water, both of which have potential Alaska North Slope (ANS) use. Long-term, the gas could supplement export sales gas. Hydrate-sourced gas could also supply significant fuel for potential thermal recovery of the geographically-coincident 20-25 billion barrels viscous oil resources. Low-salinity water floods and/or steam-floods could use the fresh water. Gas hydrate reservoirs may also provide an attractive CO_2-sequestration option during future gas sales.

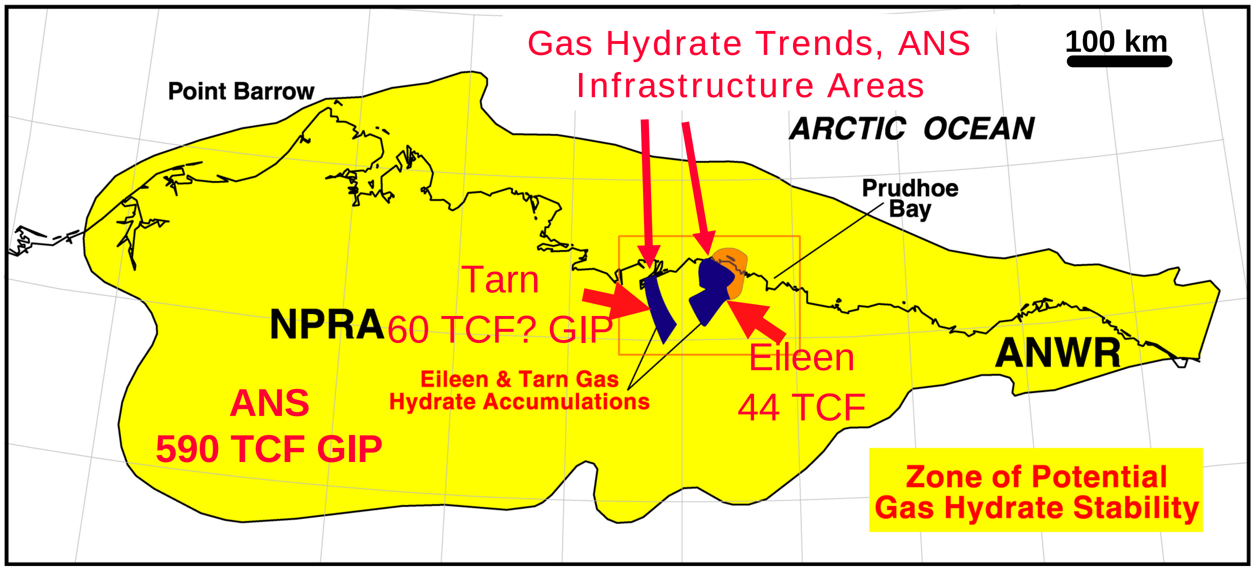


Figure 1: ANS Gas Hydrate Stability Zone Extent. (Courtesy USGS).

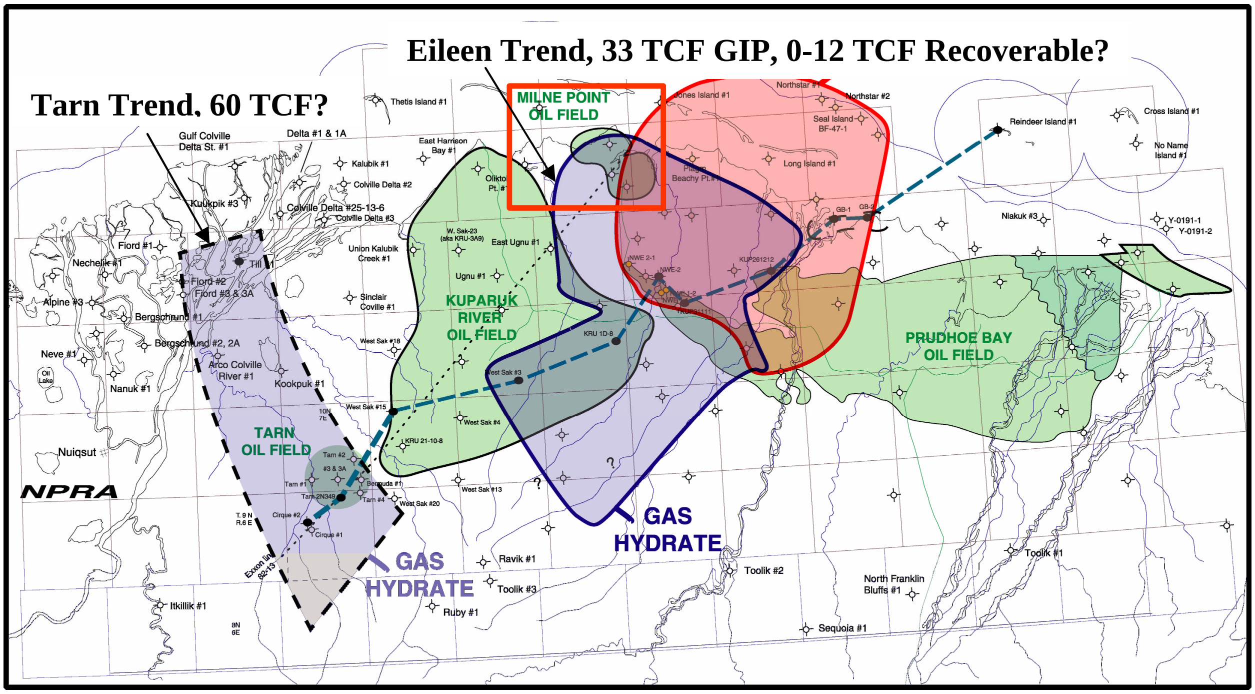


Figure 2: Eileen and Tarn Gas Hydrate Trends and ANS Field Infrastructure (modified after Collett, 1998).

The CRA project is characterizing, quantifying, and evaluating the potential gas hydrate resources in the Prudhoe Bay Unit - Kuparuk River Unit - Milne Point Unit area and has selected The MtElbert prospect site to be drilled as a Phase 3a Stratigraphic Test within MPU in 2007. The project research and development includes:

- Phase 1-3: Characterize reservoirs and fluids to validate existing resource estimates and determine resource extent and connectivity in the area-of-interest
- Phase 2-3: Determine resource recovery factor and associated productivity and commerciality through reservoir and economic modeling
- Phase 2-3: Develop principles and practices to safely drill, complete, and produce or production test shallow gas hydrate and associated free gas resources
- Phase 2-3: Develop procedures and guidelines to determine the technical and economic feasibility of producing natural gas from gas hydrate-bearing formations
- Phase 3a: Drill and acquire data in a Stratigraphic Test of gas hydrate-bearing formations
- Phase 3b (unapproved): Perform long-term production testing within gas hydrate-bearing formations

BPXA and USDOE are partnering with the United States Geological Survey and collaborating with the ASRC Energy Services, the University of Arizona Tucson, the University of Alaska Fairbanks, Ryder Scott Co., APA Engineering, and others to develop reservoir and economic models, determine the technical feasibility of gas hydrate production, and potentially enable future exploration and field extension into this unconventional resource. The large magnitude potential in-place gas hydrate resource (40-100+ TCF) and concurrent ANS conventional gas commercialization studies created timely industry-government-academic alignment for this resource assessment. The Gas Hydrate project will directly assess the resource component of gas hydrates in arctic regions beneath existing oil and gas facility infrastructure. Demonstration of gas hydrate and associated free gas as a possible economic resource could lead to future gas hydrate development.

BPXA plans three off-ice appraisal wells / data acquisition programs within MPU in 2007. The gas hydrate appraisal is the first well and viscous oil appraisal wells within the northwestern area of the Milne Point Unit will comprise the latter two wells.

Core, logs, and MDT data will be critical to help determine the resource potential of methane hydrate within the study area. Alignment with DOE objectives to determine the resource potential of methane hydrate by 2015 helped enable continuation of the CRA into Phase 3a. The determination of locally derived rock and reservoir properties data is considered critical for properly characterizing the Sagavanirktok formation for reservoir development and potential depletion plan purposes. Only a few feet of conventional core were acquired within the Eileen gas hydrate trend in the 1972 Northwest Eileen State #2 well.

The MtElbert is one of 14 mapped gas hydrate prospects within the MPU that may contain a total of 600-700 BCF gas in-place. The prospect is a 3-way fault-bounded structural trap within the northwestern portion of the Eileen gas hydrate trend and may contain up to 90 BCF gas in-place (Figure 3).

Total cost of the well the MtElbert-01 Sagavanirktok drilling and core, log, and MDT data acquisition is estimated to be $4.1-4.8 MM, depending on operations contingency costs.

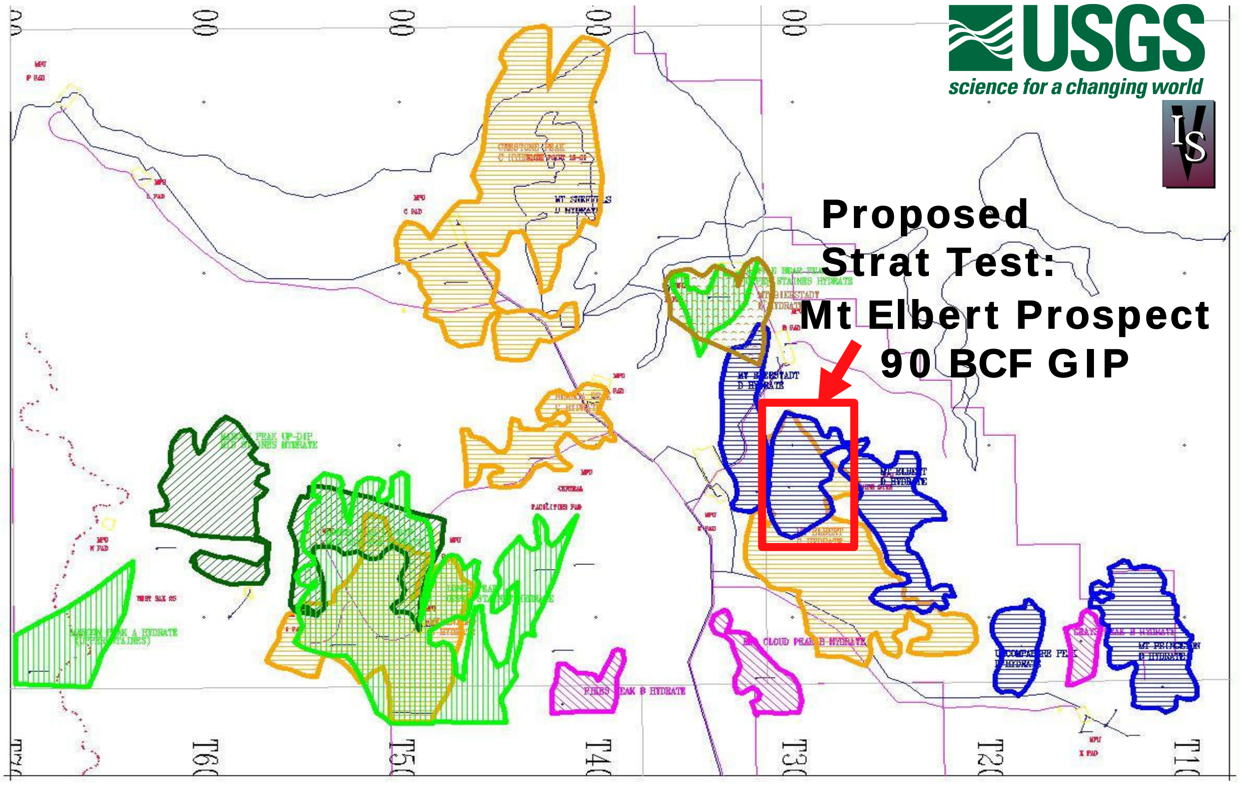


Figure 3: Gas Hydrate prospects within MPU

9.2.1.2 Coring Requirements

The MtElbert-01 well is planned to acquire 400-600 feet of wireline-retrievable core from 2-3 major reservoir sand intervals that are interpreted from the seismic data to contain gas hydrate within the Sagavanirktok intervals shown in Figure 4. The reservoir properties and lateral continuity of the Sagavanirktok zones are relatively unknown.

The core point in this well will occur just below the surface casing point set in the shalier section below the Zone E just prior to penetrating the top of Zone D (Figure 4). The projected core point is 2000 feet TVDss (but may be subject to change if the well plan requires a final modification following correlations from the MWD logs in the surface hole). Once the Sagavanirktok zone D and C-sands have been cored, the coring in the Sagavanirktok formation is planned to continue through the Zone B reservoir interval, if time permits. Zones D and C are currently interpreted to be fluvial-deltaic sands and Zone B is interpreted to be marine. These zones are interpreted to contain gas hydrate, water, and possibly free gas as pore-filling fluid phases.

The core point for the MtElbert-01 well will be picked by the wellsite geologists based on MWD log correlations from the adjacent MPU E-26 and B-01, B-02, B-22, and other E-pad offset penetrations. The MtElbert-01 well LWD logging tool will be placed as close to the bit as possible in the surface hole to minimize core depth point prediction uncertainty.

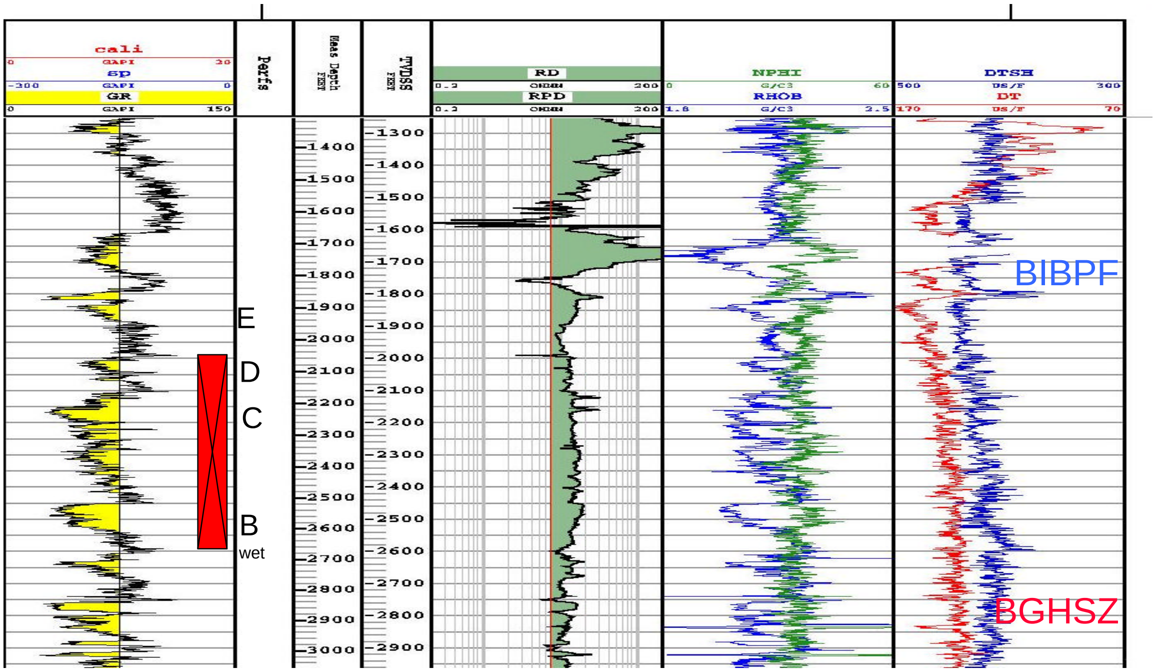


Figure 4: MPE-26 Type Log showing planned intervals of wireline log and core data acquisition between Base of Ice-Bearing Permafrost (BIBPF) and Base Gas Hydrate Stability Zone (BGHSZ).

The criteria for ending the planned Sagavanirktok formation core program are as follows:

1. The full 600 feet of Zone D and Zone C through base Zone B interval core has been recovered as illustrated in Figure 4, or
2. If coring across the targeted Sagavanirktok intervals have not been completed but the core acquisition AFE limit has been reached (i.e. 48 hours in base-plan, with up to 24 hour contingency time)

The well track is planned to be vertical throughout this interval at a maximum inclination not to exceed 15 degrees. Coring point and TD criteria are specified in the TD criteria section of the Statement of Requirements (SOR) form.

The purpose of obtaining the core is to characterize the following reservoir properties to help reduce subsurface uncertainties from which an appropriate understanding of gas hydrate-bearing reservoir properties can be ascertained. The MtElbert-01 core onsite subsampling analysis objectives are summarized below:

The MtElbert-01 core onsite subsampling analysis objectives are summarized below:

- Confirm gas hydrate and reservoir characterization interpretation
- Obtain whole-round cores for later porosity, permeability, and fluid saturations for log model calibration, and potential resource assessments.
- Sample mineralogy and lithology for log model calibration, and understanding formation physical and mechanical properties

- Sample gas hydrate and pore water geochemical and microbiological properties to understand the origin of gas hydrate and implications for vertical and lateral compartmentalization within variable lithologies.
- Sample biostratigraphic markers, which will aid in constraining and/or defining regional stratigraphic correlation horizons.

Core will also provide critical information on reservoir quality, interpreted reservoir lateral continuity, reservoir fluids, hydrocarbon in-place, resources, potential deliverability, well placement and drillability. Specific post-well core studies will include the following (subject to budget availability):

- Core-derived Rw/Sw (gas-hydrate-in-place)
- Sedimentology (well placement, reserves)
- Poroperm (reserves, well productivity)
- Reservoir quality (well placement)
- High resolution biostratigraphy (drilling)
- Vertical and horizontal heterogeneity description (compartments, depletion plan)
- Coreflood tests (relative permeability)
- Petrophysical tests

Primary Risks / impacts / mitigations to good coring performance and the overall well objectives on MtElbert-01 are detailed in the Core Risk Register. The top 6 include:

1. **Stage:** Planning and preparation / **Risk**: Coring equipment and personnel not available when needed (Corion's wireline system, Drill Cool mud chilling system, USGS/DOE equipment and supplies, Core trailers) / **Impact**: Unable to core well, possible rig standby waiting on equipment / **Mitigation**: Prepare detailed coring plan. Work with vendors to confirm equipment and personnel are available (and properly certified and trained for slope). Prepare checklist and distribute. Prepare checklist for training and slope clearance.
2. **Stage:** Planning and preparation / **Risk**: Coring procedure and processes and core handling procedure poorly understood leading to HSE incident / **Impact**: Cannot proceed with work or HSE impact / **Mitigation**: Proper FEL planning and documentation, proper ATP. Proper JSA/JRA at rigsite pre-core with dress rehearsal. Detailed coring pre-spud on rig with rig and coring crews.
3. **Stage:** Operations **/ Risk:** Mud chiller fails / **Impact:** Cannot proceed with drilling/coring well, poor data acquisition, poor borehole conditions, loss of borehole, potential well control issue / **Mitigation**: DrillCool equipment must be checked out and working ahead of time, and working at Doyon14. On location when Doyon14 moves on ice pad for spud ~Feb. 1st.
4. **Stage:** Operations **/ Risk:** Core point picked too shallow or too deep (core point based on isopach ahead from casing shoe) / **Impact:** Core the wrong interval. Pick too shallow and not enough time to obtain 600' of cored interval. Pick too deep and drill up main cored interval. Don't have enough wiggle room in timing to have mis-picked core point / **Mitigation**: Have rig geologists and USGS/DOE in agreement for core point.

5. **Stage**: Operations / **Risk**: Swabbing during POOH / **Impact**: Well control incident / **Mitigation**: Prepare tripping guidelines to include maximum speed per wireline run, pump out of open hole. Model swab prior to coring and develop tripping schedule. Corion Input per Doug Kinsella: "There is a great deal of flexibility here. If we close the top valve on the diverter sub we can pull at 200 feet per minute and not swab the well at all. If we leave the valve open we will most likely swab about 10 gallons There is no downside to the leaving the valve closed and pulling at the above rate. The rates are dealing with gas expansion in the core, if no free gas is expected, then we just pull at 200 feet per minute."
6. **Stage**: Operations / **Risk**: Gas liberation at rig floor / **Impact**: HSE incident, poor core quality / **Mitigation**: Prepare tripping guidelines to include maximum speed per stand and per #5 Corion input. Chilled MOBM.

Additional concerns include, but are not limited to:

- Jamming of the semi-consolidated water-bearing reservoir sands within the Sagavanirktok formation,
- Poor recovery of the gas hydrate-bearing reservoir intervals,
- Poor displacement of water based drilling mud with oil-based coring fluid or excess water in MOBM system,
- Borehole problems due to mud-chilling difficulties or gas dissolution from gas hydrate or associated free gas-bearing formations,
- Core face obscured by opaque oil-based mud with black Gilsenite additive causing difficulty in subsampling

All Risks to coring performance will be examined in detail and prevention/mitigation agreed with the operations team during the pre-coring risk register assessment.

Above all, MtElbert-01 coring operations must be done without hurting people or damaging the environment in any way. BP HSE practices will be rigorously followed at all times and if anyone sees any cause for concern regarding procedures described in this document, they should let the authors or BP management know immediately.

9.2.2 MUD CHEMISTRY AND MUD-CHILLING SPECIFICATION

Proper mud chemistry and adequate mud-chilling are primary well objectives which will maintain gas hydrate stability, maintain borehole gauge, and maximize core recovery and quality.

9.2.2.1 Mud Chemistry Objectives

The mud chemistry objectives include:

1. Ensure that mud chemistry and temperature is fully optimized to maximize coring performance, minimize filtrate invasion into core, and maintain gas hydrate stability without affecting other well objectives or compromising drilling performance. Proper mud chilling within the 0 to 4 degree Centigrade range is critical to achieving project objectives of maintaining gas hydrate stability during coring and subsequent logging operations.
2. Ensure that mud filtrate is non-damaging to the core and does not irreversibly alter core or core fluid properties.

3. Ensure that major mud treatments are not required during coring and mud properties remain relatively constant throughout.

9.2.2.2 Safety

- MSDS for mud components, contingency chemicals, and core subsampling must be available for core team inspection.
- Appropriate personal protective equipment and barrier creams must be used by core team as oil-based mud is potentially harmful.
- For activities where significant mud contact can occur (e.g. breaking down core barrel on drillfloor), mud proof slicker suits will be worn.
- If any significant mud contact with skin occurs, the affected area will be washed immediately to prevent harm.

9.2.2.3 Operational details

A primary objective of Milne Point MtElbert-01 coring program is to determine in situ reservoir gas hydrate and water saturations. An oil based mud system with minimal water content is proposed for this core program to minimize mud filtrate invasion, and thus maximize the uninvaded diameter of the Sagavanirktok core. The oil based mud system will provide a much lower spurt loss and lower permeability filter cake than a water based mud, which should help ensure that fluid invasion is minimized and borehole and core stability is maintained. In addition to the low invasion character of oil based mud, the use of an oil based mud system should reduce jamming by reducing core barrel friction, with an increasing core length and increasing formation penetration rates.

9.2.2.3.1 Mud Requirements

Successful low invasion coring is a relationship between low invasion style coring bits and a low spurt loss, low invasion drilling fluid. The bits help by giving high ROP, by not having throat discharge ports which force fluid into the core, and by not having extra gauge cutters in the throat, which scrape off filter cake and allow more invasion. The mud is designed to build very low permeability filter cakes extremely quickly, limiting filtrate invasion. More than 50% of the filtrate in a core is generated at the core bit during the shaping of the core. Each time a PDC cutter exposes new rock surface spurt-loss occurs on that surface. This spurt-loss is due to very rapid generation of filtrate as the mud cake is forming. Minimizing the area on the core where cutting occurs is an important consideration to bit design and selection. After an intact mud cake has formed the static-fluid loss controls filtration at a much lower rate and decreases with the square root of time as the cake thickness grows. Gradually, the pressure differential required to force the filtrate to flow vertically in the core increases with core length and at several feet above the core bit depending, on vertical permeability of the rock, the pressure difference between pore space and the mud goes to zero. If a shale interval is cut, then all vertical movement of the filtrate ceases above that point as the pressure difference between mud and core immediately goes to zero.

This pressure difference between the mud and core is maintained by the low permeability of the filter cake. The lower cake permeability, the lower the filtration and the further above the core bit the pressure difference is maintained. In unconsolidated sand this pressure difference helps hold the core together so it can enter the inner barrel. When cutting shale or if the core length becomes so great that the weight of the core above causes the rock up in the inner barrel to enter plastic failure, the annulus can be lost and the core jams. The jam will begin close to the point where the pressure differential first goes to zero and as coring continues, the annulus will be lost all the way down to the core bit with the rock in plastic failure in the intervals of lost annulus.

9.2.2.3.2 Coring Fluid Design Criteria

The low invasion, equity coring fluid criteria established during the Prudhoe Bay and Pt. McIntyre equity determinations were the template for the design of the MOBM fluid. The Pt. McIntyre fluid in particular was used as a guide since it gave extremely low invasion in Kuparuk sandstone 4” cores, rarely exceeding 1/2”. There are two chances of getting accurate water saturations from an oil based mud core. Preserving some uninvaded rock is much preferred, but if invasion does occur, filtrate with a high interfacial tension relative to the native brine will probably leave the brine undisturbed. The fluid is designed both for minimal invasion and to preserve the second option through careful selection of surfactants.

The main design criteria for the MOBM fluid were:

1. The fluid must contain emulsifiers in adequate amounts to disperse any contaminating water. Only carboxylic acid emulsifiers should be used since these have been shown to have minimal effects on rock wettability while effectively emulsifying water and not yielding extremely low interfacial tensions. The emulsion stability, as measured by a Fann 23D-type instrument, should be >2,000 volts.

2. The oil/brine interfacial of the fluid must be 7-14 dynes/cm, or higher. Poly-amide emulsifiers and sulfonated surfactants should be excluded from the system, since they give very low IFT’s and strongly change rock wettability. An IFT measurement will be made with filtrate from the final formulation.

3. The fluid must have rheology that is acceptable for an effective drilling and coring fluid in this vertical hole. A yield point near 15-25 range is preferred, with 6 and 3 rpm readings in the high single digit to low double digit range. The rheology must be stable in the presence of small amounts of contaminating water. The fluid must develop sufficient initial viscosity at the mixing plant to suspend weighting material.

4. The high temperature/high pressure (HTHP) static fluid loss (at 100°F) of the fluid must be 2-4 cc's, and preferably 2 cc’s or less. When all of the components of a low invasion fluid are present, the spurt loss of the fluid tracks closely with the HTHP fluid loss. There must be no free water in the HTHP filtrate. This is more important than having an ES of 2000 volts, which is an indirect estimate of emulsion stability. Any invading water will complicate the water saturation issue.

5. The coring fluid should contain an adequate concentration of sized solids to lower the spurt-loss of the mud so that low invasion coring techniques can be used to minimize mud filtrate invasion. Past experience has shown that 100 ppb of calcium carbonate with a median size in the 5-10 micron range works very well. MI’s Safe-Carb 10 usually has a median size of 10 microns.

6. The mud should not contain an excessive concentration of salt. This is to avoid any gas hydrate dissociation and adding chloride ions to the core so that an accurate measurement of the connate water chloride ion concentration can be obtained for resistivity log interpretation, if this is needed at a later date. If the coring fluid picks up a little water, no calcium chloride should be added.

7. The mud must contain excess lime to ensure that the surfactants are calcium salts. Sodium salts of carboxylic acid emulsifiers have been shown to be more effective in lowering interfacial tensions, and calcium salts are more effective in forming water-in-oil emulsions. 1 ppb excess lime is adequate.

8. The coring fluid must have a water content of <2% by volume.

9. The drilling mud will be chilled to 0 to 5 degrees Celcius to maintain borehole and gas hydrate stability; the mud properties at these low temperatures must be monitored to prevent drilling or equipment problems. However, salt additives must be minimal to none to avoid gas hydrate dissociation and borehole erosion difficulties.

10. The mud will contain tracers in the oil from the prior well, MPF-99. The tracer for is 1-bromonaphthalene, and the recommended concentration is 100 parts per million.

11. During coring, a microsphere tracer will be added to the mud system as detailed in Section 2.3.6.

<u>Coring Fluid Formulation – See Drilling and Mud Programs for detailed mud formulation at correct (9 PPG weight and cold temperature viscocity/properties).</u>
Pilot tests were done in Houston by MI Drilling Fluids to optimize the properties of the coring fluid. A 10.3 ppg fluid will look like:

LVT-200	0.787 bbl
Claytone EM	7.0 ppb
Lime	3.0 ppb
Versa-mod Emulsifier	3.0 ppb
Versa-Trol	25 ppb
Safe-Carb 10 (10.5 micron $CaCO_3$)	90 ppb
Barite	75 ppb
1-bromonaphthalene	100 ppm

With <2% water, the formulation gave the following properties after being sheared on a Silverson mixer and hot-rolled overnight at 150 degrees F.

	70 °F	100°F
600 rpm	145	97
300 rpm	84	57
200 rpm	60	42

100 rpm	36	27
6 rpm	8	7
3 rpm	7	6
PV, cp	61	40
YP, $lb/100ft^2$	23	17
Gels(10sec/10min)	8/30	11/39
ES, volts	2000+	
HTHP(35µ), cc	1.2	2.4

Claytone EM is important because it will yield in the mud plant and allow the mud to be weighted up. Most clays do not yield well in mineral oils, especially until they have been exposed to some down-hole temperature and shear through the bit. Also, most clays give huge viscosity increases when they see a little water. Claytone EM is mostly stable to water. The low shear rate rheologies improve when the fluid is exposed to no more than 0.5% water.

Versamod is a dimer/trimer fatty acid that gives superior low shear rate rheology in the mud plant, high ES's, and very high IFT's.

Vers-Trol is gilsonite (a natural asphalt) that behaves the same way to control spurt-loss and static fluid loss as the blown asphalt used previously. The blown asphalt is a discontinued product for MI. Unfortunately we have no low invasion experience with Gilsonite only oil based mud.

Calcium carbonate is a finely ground calcium carbonate (marble) with a median particle size of 10 microns. We have used it, and similar products, on many successful low invasion coring jobs.

Mud properties must be monitored on a daily basis by MI. These mud properties must be available to the drilling foreman and coring advisor.

9.2.2.3.3 Mud Mixing Suggestions

The most critical step in mixing the mud at the North Slope mud plant was yielding the clay. Time, heat and shear were the important factors in getting a fairly complete yield from the clay. Heat the 200 bbl mixing tank of LVT-200 to 130-140°F using glycol heating lines, and supply extra shearing energy to the system via a SECO (Echols) Homogenizer pump. This produced a fluid in the Niakuk coring with almost equilibrated properties, which readily supported solids. The clay and base oil go through a visible "watery-to-creamy" transition as it yields. The other products should not be mixed through this shear device. It will reduce the average grind size of the calcium carbonate. The order of mixing is the same as the products are listed in the recommended formulation. We checked the rheology of one sample before it was hot-rolled or exposed to water. After mixing with strong shearing, the sample should have a (70°F) a YP of 23 with gels of 8/30, and a 3 rpm reading of 7.

Since keeping water to a minimum in this fluid is a key goal, the mixing pits and lines should be cleaned before mixing begins. This will also keep other emulsifiers, etc. out of the coring fluid. Sending a slug of base oil through all the pumps and lines to sweep out prior fluids, and then sucking this fluid out of the tank with a portable pump may be a useful approach. The same care should be taken with the trucks that carry the mud to the rig. The tanks should be clean and dry.

9.2.2.3.4 Tracing the Mud with 1-bromonaphthalene

The Oil-based mud utilized for the MtElbert-01 well will come used and reconditioned from the prior well, MPF-99. The tracer 1-bromonaphthalene will be present in the mud system from F-99. Mud samples from F-99 will be analyzed for information regarding potential impact on geochemistry and water chemistry.

9.2.2.3.5 Mud Sampling

Mud samples should be obtained during drilling and coring to ensure quality control and understanding of potential impacts on geochemistry and water chemistry. Samples will be acquired at 10 feet into each 24 foot core run while still have good drilling fluid circulation. Two samples should be acquired, one at suction tank and a second at possum belly. This sampling technique and interval should be communicated to the mud engineer and mud-loggers. Samples will be obtained in 1-liter Nalgene bottles to be supplied by OMNI Lab and be shipped to the following address for chemistry and microbiology analysis:

Marta Torres
104 COAS Admin Building
Oregon State University
Corvallis, OR 97331-5503

9.2.2.3.5.1 Microspherical Tracer

9.2.2.3.5.1.1 Introduction

When collecting deep subsurface cores for microbial characterization it is essential that the microbiologists can demonstrate that the microbes that they detect in the samples from the interior of the recovered cores are authentic to the subsurface and not introduced as a part of the drilling fluid (3). Accordingly, scientific drilling teams in terrestrial and marine settings have devised various quality assurance/quality control tracers that can be deployed during the coring in order to permit the evaluation of sample quality. For a number of years, carboxylated, latex microsphere tracers have been used to assure the quality of subsurface cores for microbiological analyses in deep drilling efforts conducted in Idaho (1), Washington (5), New Mexico (2), Arizona (4), and many other locations. These microspheres are non-toxic, inert and considered safe for environmental use.

9.2.2.3.5.1.2 Objective

To estimate the extent of infiltration or contamination of microbial-sized particles to the interior of cores sections that will be examined for microbiological properties.

9.2.2.3.5.1.3 Approach

1) Carboxylated, latex microspheres (Polysciences Inc., Warrington, PA) nominally 0.9 um diameter, are shipped in concentrated solution. These microspheres are conjugated with a fluorochrome (i.e., fluorescein) so they can be visualized using a microscope capable of

epifluorescent illumination. In the field prior to coring, the concentrated solution is diluted in sterile water to yield final numbers of approximately 8.75 x 10^9 microspheres per ml in a total of 100 ml.

2) When using wire-line coring, the diluted 100-ml microsphere solution is added to a sterile Whirlpak bag and this tracer bag is sealed using the wire ties. The microbeads are placed in the Whirlpak bag, sealed with the heat sealer, which leaves the Whirlpak bag wires free. The core engineer between runs attaches the while pack bag to the catcher (30 second step) as the next barrel is readied to run in-hole. Since this is done between core runs, by the core engineer on the rig floor, there is no interruption to the core process. We will supply the core engineer with a box of prepared microbead bags before coring, which will be enough to see us through all core runs.

3) The tracer bag is then attached to the inside of the shoe beneath the core barrel. The specific arrangement of the tracer bag is adapted to the type of shoe or core catcher used in the coring effort. There may be several ways to attach the tracer bag; however, the method must protect the integrity of the tracer bag that contains the tracers during the trip to the bottom of the hole so that the tracer solution is only released when the core enters the core barrel and breaks the tracer bag.

Note: If microsphere tracers are to be used frequently (i.e., every core run) then it is essential to have at least two core catcher/shoe assemblies on-site so that during any given core run in which one of the assemblies is being used the second assembly can be fitted with the tracer bag to be used in the next core run.

9.2.2.3.5.1.4 References

1. Colwell, F., G. Stormberg, T. Phelps, S. Birnbaum, J. McKinley, S. Rawson, C. Veverka, S. Goodwin, P. Long, B. Russell, T. Garland, D. Thompson, P. Skinner, and S. Grover. 1992. Innovative techniques for collection of saturated and unsaturated subsurface basalts and sediments for microbiological characterization. J. Microbiol. Meth. 15:279-292.
2. Fredrickson, J. K., J. P. McKinley, B. N. Bjornstad, P. E. Long, D. B. Ringelberg, D. C. White, J. M. Suflita, L. Krumholz, F. S. Colwell, R. M. Lehman, and T. J. Phelps. 1997. Pore-size constraints on the activity and survival of subsurface bacteria in a Late Cretaceous shale-sandstone sequence, northwestern, New Mexico. Geomicrobiol. J. 14:183-202.
3. Griffin, W. T., T. J. Phelps, F. S. Colwell, and J. K. Fredrickson. 1997. Sampling by drilling, p. pp. 23-44. In P. S. Amy and D. L. Haldeman (ed.), CRC The Microbiology of the Terrestrial Deep Subsurface. CRC Press, New York.
4. Lehman, R. M., F. F. Roberto, D. Earley, D. F. Bruhn, S. E. Brink, S. P. O'Connell, M. E. Delwiche, and F. S. Colwell. 2001. Attached and unattached bacterial communities in a 120-meter corehole in an acidic, crystalline rock aquifer. Appl. Environ. Microbiol. 67:2095-2106.
5. McKinley, J. P., T. O. Stevens, J. K. Fredrickson, J. M. Zachara, F. S. Colwell, K. B. Wagnon, S. C. Smith, S. A. Rawson, and B. N. Bjornstad. 1997. Biogeochemistry of anaerobic lacustrine and paleosol sediments within an aerobic unconfined aquifer. Geomicrobiol. J. 14:23-39.

9.2.2.3.6 Oil-based Mud Maintenance

The MOBM was tested following the MPF-99 well. The existing core fluid was diluted back 1 part LVT mineral oil to 2 parts existing core mud. The fluid was cooled to 25 degrees F outside the lab and then brought into the lab and checked at 30 degrees F. The rheology looked good from the numbers reported with an acceptable PV and YP. Fluid loss was also acceptable at 5 cc on the 20 micron Aloxite disk. The mud was reported to be free flowing when poured from the vis cup at the cold outside temperature of 25 degrees F. There were numerous additional tests performed at the rig. One involved dilution of 1 part LVT to 1 part existing core mud mixture. The results of that test showed the rheology to be too thin for our purposes. Therefore, diluting back to 50:50 is not recommended. In summary the fluid should perform well for our purposes with an approximate 1/3 dilution of LVT mineral oil.

During coring it is preferred not to make additional dilutions to the oil-based mud system, if possible. Since this project involves coring 400 to 600 feet from top Sagavanirktok “Zone D” through base “Zone B” sand, the mud may need mid-course treatments. If the viscosity or fluid loss increases too much, or some other coring specification is lost, appropriate treatments should be made, but the system should be circulated until everything is evenly distributed and coring specifications are again met. A small amount of centrifuging may be used to control mud weight and rheology, but remember that the calcium carbonate required to help for low invasion coring has almost exactly the same density as drilled solids. When slugging the pipe to come out of the hole, calcium carbonate can be used instead of barite. This allows some fresh bridging material to be introduced.

When drilling to core point and after coring when drilling the rat-hole, the simplest and most effective way to reduce viscosity will be to dilute with un-weighted mud. This pre-mix should have all products present in the proper amounts (emulsifier, fluid loss material, etc), so the properties of the system do not fluctuate much. The mix should be bled into the system smoothly over a circulation or two. Try to keep track, by mass balance, of the amount of calcium carbonate in the system. If dilution lowers the concentration below 90 ppb, then more should be added before coring commences.

9.2.3 PRE-CORING RIG SITE PREPARATION

9.2.3.1 Objectives

1. Ensure that all core team members understand and agree the detailed objectives of the core operation so a safe and effective operation can be successfully accomplished.
2. Ensure that the core operations can be organized in harmony with other essential rig operations and objectives and in compliance with established HSE requirements.
3. Ensure that all of the MPU team and contractors understand how their input is vital to the success of the operation.
4. Ensure that all core processing and analysis equipment items are evaluated prior to acceptance in-place and are in safe and effective condition.

9.2.3.2 Safety

- Coring and core processing is a non-standard operation and will most likely be new to some of the rig crew.
- All core operations will be discussed with rig management and optimized to fit in with local requirements to ensure a safe and effective operation.
- The number of people involved in the rig floor handling will be kept to the minimum required with ReedHycalog (Corion) responsible for the core from acquisition through initial laydown in the Doyon14 pipeshed.
- MtElbert-01 will obtain up to 600 feet of gas hydrate-bearing core and will require specified onsite core processing for acquisition of time and temperature-dependent measurements, so manpower management and timelines will be critical to safety and operational success.

9.2.3.3 Operational Details

9.2.3.3.1 Communication

- The core team will meet with the BP Drilling Supervisor and Toolpusher to discuss the proposed coring and core handling processes and to achieve a dry-run procedure prior to initial core acquisition. Roles and responsibilities should be reviewed and agreed. Any hazards must be identified and discussed. Appropriate working procedures must be agreed and need for permits and safety assessments defined.
- Further pre-coring meetings will be arranged as required around drilling operations and rig schedules. Meetings will include presentation of coring objectives, discussion of best practice, evaluation, and means of mitigating risk.

9.2.3.3.2 Equipment Evaluation

- MPU and BP safety staff will evaluate all coring, core handling, core processing, core subsampling, and core preservation equipment prior to acceptance for onsite work.
- Core team will evaluate and setup all coring, core handling, core processing, core subsampling, and core preservation equipment as soon as possible after arrival on the rig.
- Core team and company representative will evaluate core handling equipment and process for compatibility with all rig equipment as soon as possible after arrival at site.

9.2.3.3.3 Core Team Members, Roles and Responsibilities

The MPU core team is detailed in the MtElbert-01 roster, is divided into 2 12-hour shifts and is as follows:

- 1 BP MPU Operations Geologist, oversight
- 1 BP Core Specialist (optional), oversight
- 4, 2/shift Reed/Hycalog (Corion) lead core engineer and wireline engineer
- 4, 2/shift Omni Labs core marking, breaking, gamma, photo, and preservation staff
- 8, 4/shift USGS, USDOE, and Oregon State University core subsampling staff (pore waters, geochemistry, microbiology, gas hydrate-specific core properties analyses); the below table summarizes these responsibilities
    - 2, 1/shift Organic Geochemistry and Microbiology subsampling in core trailer

    - 2, 1/shift Physical Properties subsampling in core trailer
    - 4, 2/shift Inorganic Geochemistry (water sampling) in geotrailer; including single-shift thermodynamic measurement testing (DOE), if time permits
  - 3, 1.5/shift, 1 BP Contract 1 USGS, and 1 DOE (swing-shift) shift-lead core and subsample selection geologists and be responsible for core lengths, core tops, etc; the below table also lists the 3 core shift managers/supervisors

Robert Hunter	ASRC Energy Services	Casing/Core/TD Wellsite core shift mgr
Tim Collett	US Geological Survey	Casing/Core/TD Wellsite core shift mgr
Ray Boswell	US Department of Energy	Core Handling and Swing Shift supv.
Bill Winters	US Geological Survey	Core Sampling, physical properties
Tom Lorenson	US Geological Survey	Core Sampling, GeochemistryMicrobiology
Bill Waite	US Geological Survey	Core Sampling, physical properties
Warren Agena	US Geological Survey	Core Sampling, Water Chemistry
Rick Colwell	Oregon State Univ	Core Sampling, Geochemistry/Microbiology
Marta Torres	Oregon State Univ	Core Sampling/Water Analyses Lead
Kelly Rose	US Department of Energy	Core Handling/Core Water Chemistry
Eilis Rosenbaum	US Department of Energy	Core Handling/Water Chemistry/Thermocond.

- The BP Drilling Supervisor is responsible for all coring operations on Doyon-14. The following list describes the principal roles and responsibilities of the ‘core team’ members, all of whom report to the BP Drilling Supervisor while on Doyon-14 for coring operations.
- The BP MPU Operations Geologist is responsible for subsurface communication from the scientific staff to the BP Wellsite Leader (Company Man).
- The Core shift leads are responsible for coordination of core data, sample dispatch and operation geological input into the coring program in an oversight role.
- The BP core specialist is responsible for technical guidance, team coordination and assurance of coring and core acquisition in an oversight role.
- ReedHycalog (Corion) are responsible for supplying all equipment, manpower and expertise for core acquisition through core lay-down in pipe-shed,
- Omni Labs staff will be responsible for inner core barrel marking, whole core measurement, marking, preservation, wellsite transportation, gamma, IR-camera (if used) processing, assistance with USGS onsite subsampling program, bulk core stabilization by freezing, onsite core storage, core transportation to Anchorage site, and post-program routine and specialized core analyses.
- OMNI Lab staff will be responsible for shipping other frozen samples together, including mud samples, State of Alaska chip samples, pressure vessels; recommend 3rd party shpping company, World Courier, a common shipper for these types of materials.
- Science Party will be responsible for return of equipment shipments and certain specialized core subsample shipments.
- Canned cuttings and samples will be shipped by USGS to USGS at Menlo Park

9.2.3.3.4 Selection and Set-up Core Processing Area

- Select a core processing area which will not interfere with other rig activities and enable maximum onsite processing and sampling of gas hydrate-bearing core properties.

- Conduct area safety assessment, check for potential foot/tripping hazards, overhead obstructions that might impair initial pipeshed laydown of core by crane.
- Check rig operations and harmonize core operations for safety and minimum impact.
- Check permit procedure and nominate responsible persons to ensure compliance.
- Arrange the equipment in the core processing areas for ease of operation and safe routing of compressed air and electrical lines.
- 2 core processing trailers will include the cold Corion trailer and the warm geotrailer needed for the onsite core subsampling, processing, and data acquisition operations. 1 office trailer with lighting and power supplies will also be needed. A refrigerated truck will also be onsite for core storage and transportation provided by OMNI for consistent temperature maintenance of the processed core. Figure 5 illustrates the rigsite layout.
- Gas sniffers will be provided by BP HSE in the core processing trailer(s) to provide assurance for electrical or non-intrinsically safe equipment operations during hot-work permitted operations; detailed protocols will be developed onsite during JRA's
- The installation of all equipment is to be approved by the Doyon-14 Drilling Supervisor. The rig electrician is responsible for all connections.
- The layout of the core processing area on Doyon-14 will be reviewed and agreed by the lead coring engineer, and drilling supervisor. The diagram (Figure 5) shows the layout used on Doyon-14 to indicate the scale of operations and is included for general guidance.

9.2.4 PRE-CORING BOREHOLE CONDITIONING FOR GOOD CORE

9.2.4.1 Objectives

1. Ensure that the borehole is prepared in such a way that the first run-in-hole (RIH) with the core barrel takes minimum time and incurs minimum risk (i.e. hole is on or over gauge, straight, has no micro-doglegs, is free from cuttings and cavings and is stable).
2. Ensure that the borehole is prepared in such a way that the first coring run delivers good quality core with maximum coring length and recovery.
3. Obtain maximum valuable core in minimum cost / rig time overall.

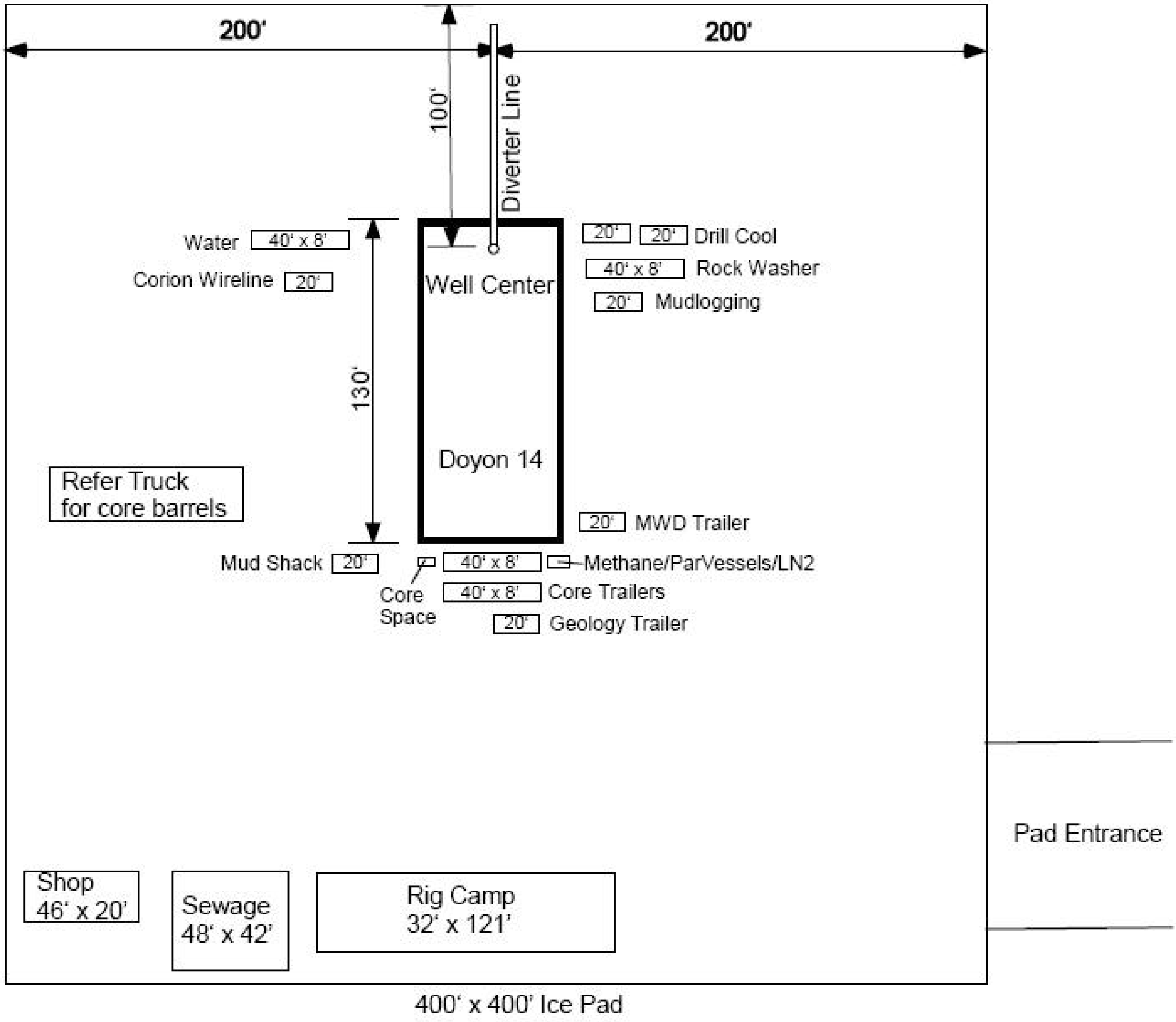


Figure 5: Ice Pad and Rigsite layout diagram. Note that Rig Camp and facilities will likely be staged on MPB-pad, approximately 1 mile to the north.

9.2.4.2 Safety and Risk

- Core point will be selected using the offset MtElbert-01 offset logs (MPE-26 and other E-pad, B-22, and B-01) data. Well control requirements take precedence over any technical recommendations made for improved coring practice.
- Hole geometry has been designed to help ensure that the drilling assembly can remain on or near bottom without risk of sticking during wireline retrieval of core barrel. If hole problems or sticking do occur, the drilling assembly may be tripped the 100 to 700 feet into the surface casing following each core run.
- The Reed / Hycalog (Corion) wireline-retrievable core system is “new to Alaska North Slope operations” and care must be taken to ensure this new kit is fully compliant with safe operations.

- The DrillCool mud chilling system is new to BP and Doyon and care must be taken to ensure this new kit is fully compliant with safe operations.
- The reservoir section may be penetrated with moderate overbalance. Good procedure to avoid differential sticking of the drilling BHA is essential and very dependent on maintaining gas hydrate stability zone temperatures through mud-chilling.

9.2.4.3 Operational details

- It is intended that Sagavanriktok section in MtElbert-01 will be cored using Corion's Wireline Express 3-inch by 24-ft core barrel assembly. Is essential that the pre-coring hole is finished using a BHA and drilling practice that will maximize the chance of trouble free tripping, core recovery, and an effective core run.
- The most effective method of finishing the original hole to core point such that the core run can be accomplished without extended reaming will depend on local conditions and experience. The team will design the best pre-coring BHA to optimize directional MWD and pre-coring requirements and will review options as the well progresses toward core point and through core intervals. The coring will purposefully drill with 7 7/8" bit to be reamed out to 8 3/4" prior to the extensive planned logging and MDT operations. **NOTE that the 8 ¾" hole size is different than the 8 ½" as planned in the SOR.**
- If there are indications of junk in the hole after pulling the pre-coring BHA then the likely type, amount and location of junk must be established. The likely impact of this junk on coring operations must be assessed and a clean-up run considered. A junk basket may be run in the BHA used to drill to core point if this is considered to be useful and acceptable.

9.2.5 GEOLOGICAL CORE POINT and CORING TERMINATION CRITERIA

9.2.5.1 Objective

The MtElbert-01 well is planned to retrieve 400 to 600 feet of approximately vertical core from the top Sagavanirktok "Zone D" to the base Sagavanirktok "Zone B" sand reservoir (Figure 4).

This gas hydrate-bearing Sagavanirktok core procedure applies to the interval illustrated in Figure 4. The core point will be picked below interpreted ice-bearing permafrost and near 2000 feet TVDss based on MWD log correlations in the surface hole to offset well Sagavanirktok stratigraphy. The core point in this well will occur near the top of the Sagavanirktok "Zone D"; however, the exact core point is subject to change if the well plan requires a final modification prior to spud or during drilling operations.

9.2.5.2 Safety

- As core point will be picked within the reservoir section, the geologist, mudloggers and driller should work closely to ensure effective well control.
- During wireline retrieval of core, care must be taken to not "swab" excessive pore fluids up the drill-string. This interval has not been penetrated at this location and the exact nature of the pore fluids, while interpreted to contain gas hydrate, is not known; pore fluids may include water, gas hydrate, and/or free gas.

- Well control and assurance of delivery of the total objectives of the well will take precedence over geological core acquisition and termination criteria.

9.2.5.3 Operational details

- The onsite geologists will pick core point based from extrapolated offset well log data (MPU E-26, B-01, B-02, and B-22 and other E-pad wells) and as described below.
- The senior project geologists, Tim Collett and Robert Hunter, in consultation with the BP Operations Geologist, Micaela Weeks and the core team, will make all geological coring termination decisions except those related to budget constraints should the operation exceed the planned 2-3 days.

9.2.5.3.1 Start and termination of coring.

- The core point will be picked in the Sagavanirktok formation and extrapolated from offset well log data. The core point in this well will occur near the top of the Sagavanirktok "Zone D" (Figure 4). The projected core point is 2000 feet TVDss (but may be subject to change if the well plan requires a final modification prior to spud). This coring procedure will starts at the top of the Sagavanirktok "Zone D" and continues to the base of Sagavanirktok "Zone B" if coring remains within the operational time constraints of 2-3 days. The Sagavanirktok section will likely consist of interbedded fluvial to nearshore sand/silt/shale sequences which may contain a variety of pore fluids including gas hydrate, water, and free gas. The gas hydrate-bearing sections will appear "cemented" by the hydrate; any water or free gas-bearing sections will be unconsolidated.
- The criteria for ending the Sagavanirktok core program are as follows:
    1. The full 600 feet of Zone D through base Zone B interval core has been recovered (25 core trips using 24 foot core barrel length), or
    2. If coring across the targeted Sagavanirktok interval has not been completed but the core acquisition AFE limit or 2-3 day-limit has been reached.
    3. If core operations are perceived to damage the borehole such that subsequent and more critically important planned logging and MDT operations cannot be effectively or safely implemented.

9.2.6 CORE ACQUISITION

9.2.6.1 Objective

1. Cut maximum length (up to 24 feet per run) with maximum recovery good quality core within the target reservoir section.
2. Do not endanger any subsequent objectives of the well (logging, MDT Testing) by excessive borehole damage, enlargement, etc.

9.2.6.2 Safety

4. Coring will commence in open reservoir and well control requirements take precedent over technical recommendations made for improved coring practice.
5. Coring is not a routine activity, the coring engineer, core specialist, core shift team leads, and BP Operations Geologist will lead Job Risk Assessments (JRA's) and discussions with

the rig crew involved to ensure that safe and effective procedures are used before picking up the core barrel and beginning coring.

6. JRAs will be reviewed with each crew as program and shift changes occur.

9.2.6.3 Operational details

9.2.6.3.1 Core head Types and Selection

It is intended that the Sagavanirktok section in MtElbert-01 will be cored using Corion's Wire line Express 3-inch by 24 foot core barrel assembly. This system has never been run in Alaska before and it is being evaluated for possible use in an extended 70 well Ugnu Formation delineation program. The main difference between this system versus conventional coring systems is the BHA is not tripped to surface after core is cut. The BHA is tripped into the intermediate casing string only and then the core is retrieved through the drilling string via wireline.

There are a number of technical requirements for the MtElbert-01 coring operation to enable accurate reservoir evaluation:

1. Get the coring assembly to bottom without jamming and in good condition.
2. Core the target horizon to obtain the maximum length of core in good structural condition in the minimum amount of rig time.
3. Maximize core retrieval to surface rate without compromising safety due to hole swabbing; this will enable retrieving gas hydrate-bearing core samples with minimal hydrate dissociation into free gas and water.
4. Core at an acceptable ROP.
5. Core with minimum torque and torque variation to avoid any chance of damaging and losing the core barrel.
6. Core with TCC equipment and procedures to minimize the chances of tectonic sticking of the core barrel.

A range of core heads will be available for MtElbert-01, and close analysis of coring performance and resulting core quality will be made in order to get good core and to further optimize core heads for future coring operations.

The preferred core head for the 7-7/8" coring in oil based mud is the CSS 513 core head (Figure 6). Alternatives will be carried for evaluation and as back-up. Final corehead selection will be made based on prevailing operational conditions by the lead Corion coring engineer, BP Core specialist and BP drilling supervisor.

REED Hycalog
Coring Services

CORION
diamond products

CSS 513

APPLICATION

- Designed for soft to medium formations with low to medium compressive strengths in consolidated and unconsolidated formations.
- Applications include vertical, directional, horizontal and *Corion Express*^{TM} coring.

FEATURES

- Low invasion bit design
- Core bit features fluid flow ports that direct the mud away from the core, an internal lip lower shoe to seal off mud flow from the throat of the core bit, and a flush inner diameter to prevent disruption of the core's filter cake
- Excellent cleaning features for shales and other soft formations
- Core bit features larger junk slots increasing cleaning ability and removal of foreign material down hole

BIT DESIGN

Bit Profile: Flat, Rounded
Bit Body: Steel
Cutter Type: PDC (30 cutters)
Cutter Size: 13.0 mm
No. of Blades: 5
Gauge Protection: TSP

TFA: 0.98in^2 (613mm^2)

AVAILABLE SIZES

200 mm x 76 mm (Express)
200 mm x 89 mm (Express / Conv)
200 mm x 102 mm (Conv)

Figure 6: Corion CSS 513 Core Bit

9.2.6.3.2 Barrel Length and Core Run Plan

- The strength of the formation, and presence of sharp changes in rock mechanical properties usually controls the length of core that can be cut before core breakage and jamming or milling occurs.
- In the Sagavanirktok, core barrel length will not be set to accommodate the longest core that can be cut with the Corion assembly (24 feet). There are clear advantages to taking shorter cores (i.e., ease of top side handling and processing, core quality, etc).
- Doyon-14 operations must be designed to minimize operational risk. If drilling and coring operations in MtElbert-01 are trouble free with no high erratic torque, stalling of the BHA, tight spots and sticking during tripping into intermediate casing; the Wireline Express coring system will remain in place to the completion of the well. In the event of operational problems with using this wire-line retrievable system, it may be replaced with a conventional system supplied by Reed-Hycalog, if time permits.

9.2.6.3.3 Core Size

- In the 7-7/8” hole, the actual core size will be 3 inches.
- The 7-7/8” hole will be reamed out to 8 1/2 inches prior to logging operations.

9.2.6.3.4 Inner Barrel Type

The inner barrel is composed of steel and is 24 feet long (Figure 7). Placed inside of the steel inner barrel are two aluminum sleeves. Each sleeve is 12 feet long. The liners are slotted in order to provide quick access to the core sample. Caution and care must be taken when removing each liner and processing it.

Figure 7: Corion inner core barrel with slotted liner.

9.2.6.3.5 Core Catchers and pilot shoes

The core catchers that will be utilized for the Hydrate section will utilize a dual catcher system. The core will enter through the pilot shoe and pass through a slip catcher that has a grit abrasive coating. The core will then pass through a finger basket catcher (Figure 8) that has the ability to contain rubble or unconsolidated core. These two different style catchers work in conjunction with each other greatly increasing core recovery. An average of 95%+ is maintained in Western Canadian Heavy Oil coring.

Figure 8: finger basket core catcher.

All ACG coring shows that core cut in-gauge can consistently be caught using conventional spring catchers. The Design of the CSS-513 core head utilizes a back up gauge cutter should the primary cutter become damaged during coring operations.

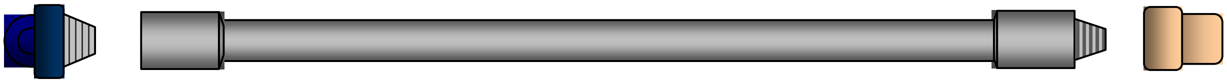
All catchers & pilot shoes should be inspected to ensure that they are in good condition by the coring engineer before use. The primary plan is to use heavy duty spring catchers.

Extended lower shoe format pilot shoes (and core heads) are preferred. The CSS-513 is a Low Invasion face discharge core head. The lower lip of the shoe is extended into the throat of the bit to minimize the amount of fluid passing by the core while coring. The TFA is the bit is normally set at 1.0 in^2 but can be adjusted in the R&M Facility prior to shipping to the rig.

Pilot shoes must be compatible with the core head selected; the corehead TFA must not be significantly reduced when the core is pulled and the inner tube stretched. Through the design of the CSS-513 it is impossible to restrict the flow even if a failure occurred and the shoe completely bottomed out in the bit.

9.2.6.3.6 Picking Up Corion Express Drill Pipe

1. Have a safety meeting with rig crews prior to picking up any tools to point out hazards and discuss safe operating practices.
2. The Corion Express drill string is a 5” (127mm) drill pipe with 4 ½” IF modified connections. Each drill pipe is approximately 9.45m in length with an ID of 108mm.
3. The Corion Express drill pipe must have pin protectors on at any time the pipe is being raised to the floor and must not be removed until the pipe is hanging vertically in the derrick. Failure to follow these procedures could cause damage to the drill string.
4. Pick up nubbins must be installed in the box end of each Corion Express drill pipe in order to ensure that no seal damage occurs. Attach the rig’s winch line to these pick up nubbins in order to hoist Corion Express pipe up the V-door.



5. When picking up the drill pipe, remove the pin protector from the pipe and drift the pin end of the pipe as it is hanging vertically in the derrick prior to making the connection.

9.2.6.3.7 Coring BHA

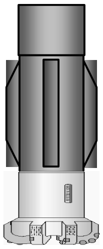
- The coring BHA run should ideally be the minimum required to apply necessary WOB, with weight coming from drill collars (neutral point in drill collars).
- The coring BHA should also be stabilized to improve coring performance and minimize the chance of differential sticking.
- Consider use of roller reamers in the BHA to minimize torque.
- Strongly recommend the use of a flapper type float sub to prevent cuttings backflow into the string which might lead to barrel blockage. However, this is an impossibility as there is no flapper float available that will have an opening large enough to pass the core barrel through. The drill pipe can be easily circulated by removing the inner barrel and pumping through.

Figure 9 shows the planned core BHA.

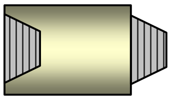
9.2.6.3.8 Assembling Coring Tools

1. Pick up the Corion Express core barrel and hang it in the derrick with the elevators or the top drive. The outer barrel typically arrives in the field with the seat sub, 1’ spacing sub and a pick up sub attached to it.

2. Remove the pin protector from the outer barrel and screw the core bit on. Install the bit breaker onto the bit and torque the bit to 26,000 ft-lbs (DDD threads) or to 10,000 ft-lbs (4 ½” IF threads).



3. Lower the outer barrel assembly into the hole and set it in the slips with a collar clamp.
4. Remove the 1’ spacing sub and the lifting sub from the outer core barrel. The seat sub will still be attached to the top of the outer barrel.



HD Corion Express Collars
OD=6.5”
ID=4.25”
Length=31 ft

Stabilizer
Body OD=6.5”
ID=4.25”
Blade OD= 7.8”

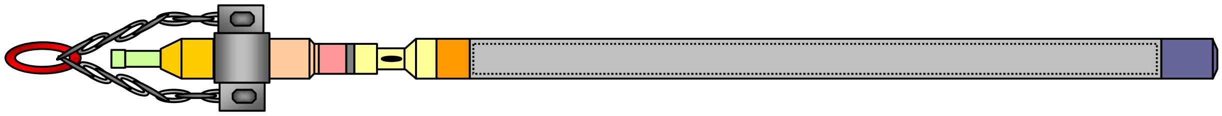
Seat Sub
OD=6.5”

Outer Tube
Body OD=6.5”
ID=4.25”
Length=22ft

Core Bit
Blade OD=7.8”
Size= 7.875” x 3”
CSS 513

Figure 9: Planned Core BHA

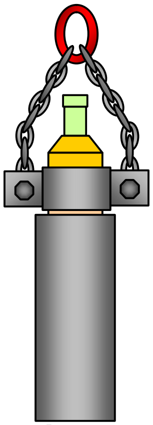
5. Pick up the inner barrel assembly from the catwalk.
    a) Attach the rig’s winch line to the pressure head clamp, which is fastened to the top of the inner barrel assembly.



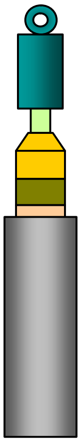
b) Ensure that the wheeled cart is attached to the bottom of the inner barrel to protect it while it is being raised up the V-door.

c) Slowly raise the inner barrel assembly up the V-door and remove the wheeled cart once the assembly is hanging vertical in the derrick.

d) Slowly lower the inner barrel assembly into the outer core barrel in the table with the winch line. The pressure head clamp will rest on the box end of the seat sub attached to the outer barrel.



e) Remove the rig's winch line from the pressure head clamp. Fasten the birdhouse clamp on the top of the rope socket of the inner barrel assembly and attach the rig's winch line.



   f) Slightly raise the inner barrel assembly in order to remove the pressure head clamp from the assembly using a 1 ¼” wrench.

   g) Once the pressure head clamp is removed, lower the inner barrel assembly into the outer barrel. Once seated, remove the birdhouse clamp.

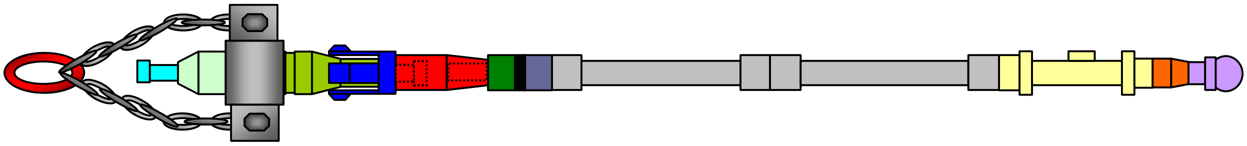
6. After the inner barrel assembly is seated, insert the pick up sub and 1’ spacing sub into the seat sub attached to the outer barrel.
7. Latch the elevators to the pick up sub.
8. Check the lead between the inner barrel’s bottom shoe and the bit.
   a) Hoist the core barrel assembly.
   b) Remove the collar clamp from the outer barrel, remove the slips and hoist the outer barrel upwards out of the table to chest height. Install the hole cover.
   c) The core hand will check the lead in order to ensure that the inner barrel assembly is free moving within the outer barrel. A gap of approximately ¼” (6mm) must be between the inner barrel’s bottom shoe and the bit.
9. Remove the hole cover and lower the outer barrel back into the table. Insert the slips and install the collar clamp on the outer barrel.
10. Pressure test the inner barrel assembly.
    a) Set the core barrel assembly back in the table with the slips and a collar clamp. Remove the pick up sub but do not remove the 1’ spacing sub.
    b) Attach the kelly (or top drive) to the outer barrel assembly. Bring the rig pumps up to speed to achieve a flow rate that is between 0.75 m^3/min and 1.0 m^3/min.
    c) The core hand will record these numbers (SPM, flow rate, operating pressures, etc.) and will ensure that the inner barrel assembly is properly seated.
    d) Turn off the rig pumps. Break the connections between the kelly (or top drive), the 1’ spacing sub and the seat sub.
    e) Remove the 1’ spacing sub from the outer core barrel and put it aside.
11. Remove the inner barrel assembly from the outer barrel.
    a) Attach the birdhouse clamp to the rope socket of the inner barrel assembly.
    b) Attach the rig’s winch line to the birdhouse clamp and lift the assembly upwards approximately 0.30m.
    c) Attach the pressure head clamp to the inner barrel assembly. Lower the assembly back into the outer barrel and have the pressure head clamp rest on the box end of the seat sub attached to the outer barrel.
    d) Remove the birdhouse clamp from the rig’s winch line. Attach the winch line to the pressure head clamp on top of the inner barrel assembly.

e) Slowly raise the inner barrel assembly and remove it from the outer barrel in the table.

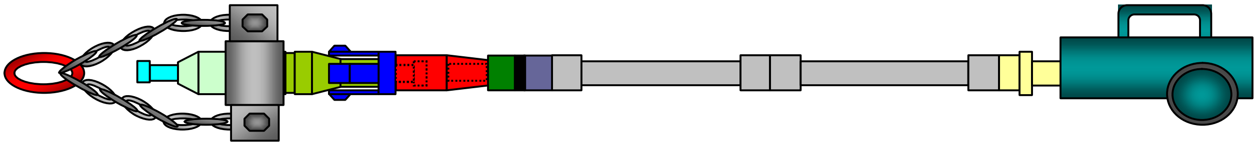
f) Attach the wheeled cart to the bottom of the inner barrel and lower it down the V-door onto the catwalk.

12. Pick up the inner drilling assembly from the catwalk.

a) Attach the rig's winch line to the pressure head clamp, which is fastened to the top of the inner drilling assembly.



b) Ensure that the wheeled cart is attached to the bottom of the inner drilling assembly to protect the insert bit while it is being raised up the V-door.



c) Slowly raise the inner drilling assembly up the V-door and remove the wheeled cart once the assembly is hanging vertical in the derrick.

d) Slowly lower the inner drilling assembly into the outer core barrel with the winch line. The pressure head clamp will rest on the box end of the seat sub attached to the outer barrel.

e) Remove the rig's winch line from the pressure head clamp. Fasten the birdhouse clamp on the top of the rope socket of the inner drilling assembly and attach the rig's winch line.

f) Slightly raise the inner drilling assembly in order to remove the pressure head clamp from the assembly using a 1 ¼" wrench.

g) Once the pressure head clamp is removed, lower the inner drilling assembly into the outer barrel. Once seated, remove the birdhouse clamp.

13. After the inner drilling assembly is seated, insert the pick up sub and 1' spacing sub into the seat sub attached to the outer barrel.

14. Latch the elevators to the pick up sub. Check the lead between the insert bit and the core bit.

a) Hoist the core barrel assembly.

b) Remove the collar clamp from the outer barrel, remove the slips and hoist the outer barrel upwards out of the table to chest height. Install the hole cover.

c) The core hand will check the lead in order to ensure that the pilot bit is seated and flush with the core bit.

16. Remove the hole cover and lower the outer barrel back into the table. Insert the slips and install the collar clamp on the outer barrel.
17. Pressure test the inner drilling assembly.
    a) Set the core barrel assembly back in the table with the slips and a collar clamp. Remove the pick up sub but do not remove the 1' spacing sub.
    b) Attach the kelly (or top drive) to the outer barrel assembly. Bring the rig pumps up to speed to achieve a flow rate that is between 1.3 m^3/min and 1.5 m^3/min.
    c) The core hand will record these numbers (SPM, flow rate, operating pressures, etc.) and will ensure that the inner drilling assembly is properly seated.
    d) Turn off the rig pumps. Break the connections between the kelly (or top drive), the 1' spacing sub and the seat sub.
    e) Remove the 1' spacing sub from the outer core barrel and put it aside.
18. Remove the inner drilling assembly from the outer barrel.
    a) Attach the birdhouse clamp to the rope socket of the inner drilling assembly.
    b) Attach the rig's winch line to the birdhouse clamp and lift the assembly upwards approximately 0.30m.
    c) Attach the pressure head clamp to the inner drilling assembly. Lower the assembly back into the outer barrel and have the pressure head clamp rest on the box end of the seat sub attached to the outer barrel.
    d) Remove the birdhouse clamp from the rig's winch line. Attach the winch line to the pressure head clamp on top of the inner drilling assembly.
    e) Slowly raise the inner drilling assembly and remove it from the outer barrel in the table.
    f) Attach the wheeled cart to the bottom of the inner drilling assembly and lower it down the V-door onto the catwalk.
19. Attach the top stabilizer to the seat sub on the core barrel. * Do not run the 1' spacing sub in the BHA.
20. Pick up the required amount of Corion Express core collars and assemble them above the outer core barrel. Torque connections up to 26,000 ft-lbs (DDD threads) or to 10,000 ft-lbs (4 ½" IF threads).
21. All Corion Express collars are zipped and picked up in the same manner as conventional drill collars.
22. Drift all Corion Express core collars in the same fashion as drifting Corion Express drill pipe.
23. Run in the hole open ended with Corion Express drill pipe. Ensure that the drill pipe is drifted prior to making up connections. Torque drill pipe to 10,000 ft-lbs (4 ½" IF threads).

9.2.6.3.9 Temperature Gauge and Rabbit

- Corion will supply a temperature gauge and rabbit connection similar to that utilized in the 2002 Mallik program.

9.2.6.3.10 Connections while coring

- There will be no connections while coring. Pup joints will be utilized to ensure there is adequate spacing to cut a full barrel. Pup joints available in 5 ft, 10 ft and 15 ft lengths.

9.2.6.3.11 Coring Termination

- Coring should be terminated when the barrel is full (i.e. the core has reached top of the inner core barrel) or when evidence of jamming has been observed. In event of a jam, the inner core barrel will unlatch itself from it's seat and an immediate drop of pressure will be observed on the rig floor. At this point, core will be tripped to surface using the defined pulling out of hole protocol (POOH).
- If coring is about to be terminated and ROP is high, consider reducing the flowrate (to a minimum safe rate) in order to ensure that there is full gauge core in catcher. This is not a typical operation when using the CSS-513. Once the core is in the catcher and the inner barrel it should not be affected by the flow rate. Normal operations would be to allow the weight to drill off at the desired depth, reduce pump to an idle (this is typically done all in the same step when dealing with an unconsolidated formation), reduce rotary to 0 RPM and then stop the pump.
- It is not recommended to spin the barrel at higher rpm to "burn core in"; the inner barrel may rotate with the outer, causing core damage. It is never a recommendation to "burn in" core. Since the Corion Express inner barrel is held in place with hydraulic thrust, it is impossible to reduce volume to "burn in".
- If low ROP suggests that the core is finishing in harder rock or has packed off, then coring should be terminated at the normal flowrate.
- If torque and pressure indicate that bottom hole conditions are not ideal and stopping the rotary with the barrel on bottom poses as significant sticking risk, the core will be broken with rotation, but it should be kept at a minimum.
- Once the core is broken, the core barrel will be reamed up and down at low rotary speeds until the hole is completely clean and torque low and steady before breaking off stands to POOH.
- Circulation after coring should be performed in a way that minimizes the risk of soft sandstone core being washed from the catcher. The preferred option is to circulate the minimum amount for well control needs before tripping out. Clean the hole by washing down and circulating bottoms-up before starting the next core run. Reciprocating during wireline core retrieval is also possible. With circulation being possible while wire line retrieving the inner barrel, some thought should be give to the amount of circulation needed before retrieving the inner barrel.

9.2.7 CORE RETRIEVAL (TRIPPING OUT)

9.2.7.1 Objective

1. Retrieve core in the minimum time without excessively swabbing the well, dropping the core, or damaging the core by either rough handling or by the expansion of escaping gas.
2. There is a great deal of flexibility here. If we close the top valve on the diverter sub we can pull at 200 feet per minute and not swab the well at all. If we leave the valve open we will most likely swab about 10 gallons. There is no down side to the leaving the valve closed and pulling at the above rate. The rates are dealing with gas expansion in the core, if we are not worried about this then we just pull at 200 feet per minute.
3. It is possible, though not probable, that the core may contain some free gas; care should be taken due to this possibility, however, most gas is likely contained in hydrate form as a solid combination of gas and water. Therefore, the pulling rates my require modification during operations depending on formation gas shows and potential for swabbing.

9.2.7.2 Safety

- The core barrel will be large diameter within drillpipe, calculate the wireline-retrievable tripping rates to prevent swabbing.
- Normal drillfloor procedure for safe tripping and wire-lining is required.
- The reservoir sections may be cored with moderate overbalance so the adoption of procedures to avoid differential sticking of the coring assembly is essential until BHA is safely tripped into the surface casing.

9.2.7.3 Operational details

9.2.7.3.1 Requirement to maximize gas hydrate-bearing core retrieval rates

Expanding pore fluids, which are unable to escape from the core while tripping out of hole, may induce whole-core dilation and/or axial vertical fracturing. This damage mechanism is most common in poorly consolidated sediments containing gas or water, or with core that has suffered a high degree of mud filtrate invasion, but is not expected in gas hydrate-bearing core. Thus, in the expected case of gas hydrate-bearing core, this core should be tripped to surface at maximum possible rates while avoiding excess swabbing.

There are three basic concerns that should be addressed in the pulling out of hole (POOH) procedure. The first will be to prevent the influx and uncontrolled expansion of gas saturated fluids into the wellbore. The second will be to prevent damage to the core due to rapid gas expansion as hydrostatic control is lowered. Mechanical damage (which can occur during tripping the drill string and handling the core) is the third concern.

While pulling the core out of hole, at the point where mud hydrostatic pressure equals gas bottom-hole pressure, gases may begin to evolve from the core. The velocity of gas flow is related to absolute pressure, rock permeability and pressure difference. At first, the gas velocity is quite low because the pressure is high and the escaping volume of gas is small. The rate of gas escape is also related to the rate of hydrostatic pressure change or rate of pulling the pipe from the well bore. The gas escape may cause the expulsion of moveable gas or filtrate and water phases that may be present in the core. However, a higher (up to 200 feet/minute as described above) pulling rate is preferred to minimize gas hydrate dissociation into free gas and water during wireline tripping.

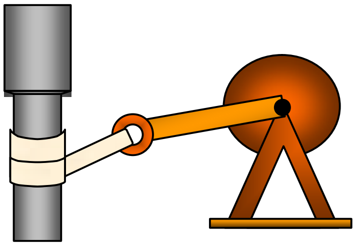
It should be noted, however, that if unexpected free gas-bearing sands are encountered, that a pressure change for one stand in a 10 lb/gal mud is 47 psi and if the gas could not escape fast enough, this total pressure could generate roughly 590 pounds of force (maximum) inside the core. Friable or unconsolidated sands can not stand such force and will be blown apart. Laboratory studies have shown that the majority of core dilation occurs over the later stages of depressurization, as hydrocarbon expansion rate increases. Field studies have also consistently shown that reducing the tripping rate in the top-hole section can protect core structural integrity, but the expected condition is that the core will contain gas hydrate and/or water as pore fluids. If the core were to contain unexpected free gas, then high pressures are most likely when the core approaches the surface where absolute pressure is low and the gas volume evolved per stand is larger.

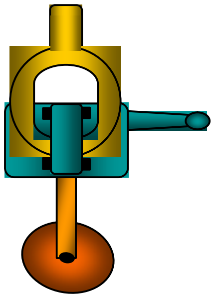
9.2.7.3.2 Rig-floor Precautions

- Braking and slip setting should be performed without jarring the core (especially near the surface). Sudden vertical shocks to the drill string frequently result in substantial core damage & may result in loss of core.
- Minimize rotation of the core barrel when breaking connections. Top drive, iron roughneck, or chain tongs should be used to rotate the pipe above connection.
- When recovering the core it will be done via wire-line. There will be no pipe conveyed in core retrieval. The wire line movement is very constant and the stretch of the line actually absorbs any shock of starting and stopping.

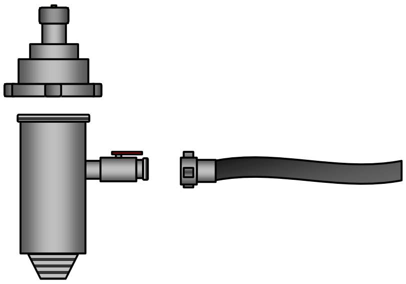
9.2.7.3.3 Rigging Up the Wire Line Unit

1. Have a safety meeting with the rig crews and wireline operators prior to rigging up wireline unit.
2. Have the drill pipe stump sticking up approximately 0.75m above the slips. Sling one sheave to the stump with a double wrap.





3. Attach the second sheave to the elevators or the top drive with the supplied slings.
4. Screw the diverter sub into the drill pipe stump in the table and attach the 2” high pressure hose.



5. The 2” high pressure hose will either be used to drain fluid to the trip tank as it is displaced, or it will be connected to the standpipe in order to pump down the inner drilling assembly.
6. String the wire line through the sheaves and slowly raise the top sheave with the elevators. Watch for loops in wireline and for tangles on the drilling floor and catwalk.
7. Raise the top drive elevators approximately 4m above the diverter sub in the stump.
8. The wireline running gear will be hoisted and lowered into and out of the diverter sub by the wireline operators.
9. Ensure that all hands are off the drilling floor when running the wireline in and out of the drill string. Maintain proper communication between the driller, core hands and wireline operators at all times.

9.2.7.3.4 Retrieving Core and Tripping Rate (out of hole)

1. Remove the kelly (or top drive) and rack back any pipe required by the company representative (i.e. to stay out of the pay zone).
2. Install the diverter sub into the drill pipe stump and attach the 2” diverter hose.
3. Rig up the wireline equipment as listed above.
4. Slowly lower the running gear into the diverter sub and attach the stripping head to the diverter sub.
5. Lower the running gear and overshot to the bottom of the hole and latch onto the inner barrel.

The following recommendations are based on good results during gas hydrate-bearing coring operations to date:

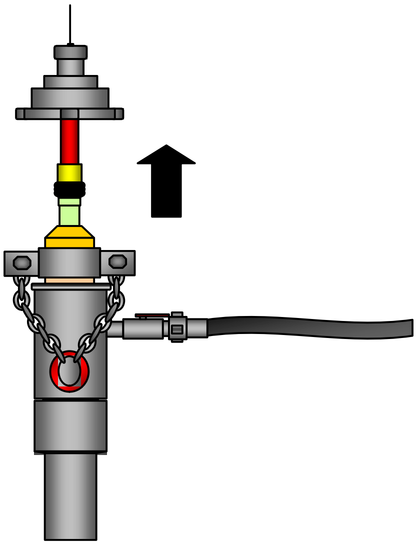
- Retrieve wireline core from TDD to 2500-ft at normal controlled rate up to 200 feet per minute
- Retrieve wireline core from 2500-ft to surface at normal controlled rate up to 200 feet per minute, preventing swabbing by slower rates if free gas is suspected to occur, depending on operational and gas show observations
- Recognize that the gas hydrate-bearing core will exit out from the gas hydrate stability field above approximately 500-600 feet TVDss. From this point, or from an agreed depth

below this point as determined by onsite operations, providing stable circulation and hole conditions are established, the core should be retrieved via wireline as quickly as possible to avoid excessive gas hydrate dissociation.

The shift-lead geologist will examine measure and record the annulus between the core and the inner barrel at each cut core face during processing and chip sampling in order to identify possible disturbance.

Provision should be made to increase or decrease the tripping rates if necessary.

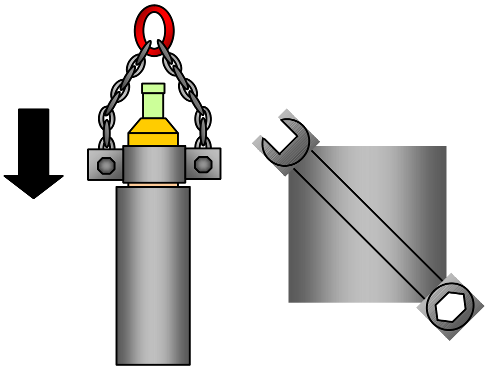
6. Remove the stripping head and pull the running gear out of the stump until the pressure head is above the diverter sub.
7. Place the pressure head clamp onto the top of the inner barrel assembly. Lower the inner barrel assembly. The pressure head clamp will rest on the box end of the drill pipe stump.



8. Allow the wire line to become slack and remove the overshot from the inner barrel.
9. Set the wire line equipment off to the side where it won't be an obstruction or a hazard.
10. Lay down the inner barrel assembly.
    a. Cautiously hoist the inner barrel assembly with the rig's winch line and attach the wheeled cart to it.
    b. Be cautious in order to prevent deflection of the core inside.
    c. Carefully lower the inner barrel assembly down the V-door using the rig's winch line.
11. If additional core is to be cut, connect the kelly (or top drive) to the drill pipe stump and circulate the hole (at approximately 0.75 m^3/min) while recovering core and preparing a new inner barrel assembly.
12. Repeat required steps as listed above.

9.2.7.3.5 Installing the Inner Barrel

- Once the core has been removed from the drill string, a second empty inner core barrel assembly can then be pumped to the coring BHA to re-dress the tool.
  1. Circulate bottoms up for approximately 5 minutes to allow for any obstruction to be cleared from the drill string.
  2. Remove the kelly (or top drive).
  3. Pick up the inner barrel assembly from the catwalk.
     a) Attach the rig's winch line to the pressure head clamp, which is fastened to the top of the inner barrel assembly.
     b) Ensure that the wheeled cart is attached to the bottom of the inner barrel to protect it while it is being raised up the V-door.
     c) Slowly raise the inner barrel assembly up the V-door and remove the wheeled cart once the assembly is hanging vertical in the derrick.
     d) Slowly lower the inner barrel assembly into the drill pipe stump in the table with the winch line. The pressure head clamp will rest on the box end of the drill pipe stump.
     e) Remove the rig's winch line from the pressure head clamp.
  4. Holding onto the pressure head clamp chain with one hand, drop the inner barrel assembly into the drill string by loosening the pressure head clamp bolt using a 1 ¼" wrench.



  5. Once the pressure head clamp is dropped into the drill string, make up the kelly (or top drive).
  6. Start the rig pumps up and circulate the inner barrel assembly to bottom with the pumps at an idle. The flow rate should be between 80 GPM to 160 GPM.
  7. The pressure will increase to a minimum of surface test pressure indicating that the inner barrel assembly has reached bottom.
  8. Once the inner barrel has seated, increase the pumps to the listed operating parameters (200 GPM and 275 GPM) and wash to bottom.
  9. Begin coring at the discretion of the core hand(s).

9.2.7.3.6 Required from Geoservices Data Engineer during each core run

- Continual monitoring of coring parameter trends with feedback to the drill floor in order to safeguard against continued drilling after core jams and pack-offs.
- If the torque, ROP or stand pipe pressure vary substantially from the baseline, a real-time plot of coring parameters (described below), from the time of dropping the ball up to the present time, should be prepared, and the coring engineer, driller, BP Operations Geologist, core shift-lead geologist, and core specialist should be notified.
- Tripping parameters should be continually monitored and compared with the theoretical fill rates and the general tripping plan. This should be done for the usual well control reasons and in order to safeguard against departure from tripping plan.
- If tripping parameters vary substantially from the plan, the driller should be notified immediately.

9.2.7.3.7 Required from Geoservices Data Engineer after each core run

- Real-time coring parameters Hook Height (m), WOH (klbs), WOB (klbs), RPM, Torque (ftlbs), SPP (psi), Flowrates (gpm), ROP (m/hr), Total Gas (%) plotted at 16cm/hr from the time of the connection in order to drop ball to time of tripping the core barrel into the casing shoe. A .pdf file on floppy disk and paper plot will be required.
- Trip monitoring data (depth of bit vs. trip rate in minutes/stand) is to be provided in Excel format and given to the BP core specialist immediately after each core trip. A paper plot of trip performance should also be produced for immediate discussion with the Wellsite leader, BP Operations Geologist, core shift lead geologist, and core specialist, in case the tripping schedule requires modification.

9.2.7.3.8 Required from Geoservices Data Engineer on completion of coring

- Excel file of coring parameters for each core on high-resolution regular depth spacing (reading every 0.5 – 1.0 metre) including ROP (m/hr), WOB (tonne), RPM, Average, Maximum and Minimum Torque (ftlbs), Flowrates in/out (gpm), SPP (psi), temperature (from Rabbit gauge), and GammaRay (if run). To be given to the core shift lead geologist on completion of the last core.

9.2.7.3.9 Required from Coring Engineer on completion of coring

- Details of the coring BHA and core barrel run for each core.
- Coring performance including WOB, ROP, torque, pressure, temperature, and comments (0.5m depth interval).

9.2.8 RIGFLOOR CORE HANDLING and CORE LAYDOWN IN PIPESHED

9.2.8.1 Objective

1. To safely remove the inner barrel and core from the drill floor to the processing area without damaging the core in optimum time at minimal cost.

9.2.8.2 Safety

1. Core laydown is not a routine activity. The coring engineer will lead a Job Risk Assessment and discussion with the rig crew involved to ensure that safe and effective procedures are used before beginning the core lay-down.
2. JRAs will be reviewed with each crew as changes occur.
3. Any misalignment of the inner tube during the cutting and the application of the shear boot may result in dropping the core onto the drill floor. This activity must therefore be conducted with great care.
4. Stringent precautions for heavy lifting must be followed with care – this is one of the most potentially dangerous parts of the whole coring operation.

9.2.8.3 Operational details

9.2.8.3.1 Requirement for specialized surface handling

- Once at the surface, the core must be quickly removed from the drill floor to allow critical path drilling operations to be carried out without delay.
- The 24 foot steel inner barrel which will contain two 12 foot aluminium liners will be laid down using the rig's winch line.
- Care should be taken during surface handling and processing of unconsolidated core to avoid core damage by inner barrel flexure and impact.
- Care must be taken to contain MOBM during core assembly retrieval to surface on rig floor and during subsequent transport to pipeshed and core trailer. Absorbent material will be required; plastic wrap will likely be required during transport from rig floor to pipeshed.

9.2.8.3.2 Inner Barrel Separation

- The Company drilling representative, BP Operations Geologist, coring engineer, core shift-lead geologists, and/or core specialist must hold informal pre-core laydown meetings with rig crew and other key personnel to highlight the importance of safe effective core handling, and to promote good teamwork.
- Gentle core handling is essential. The rig crew input is critical to a safe and successful coring operation.
- The rig floor extraction of the core assembly and the pipeshed breakdown of the core barrel, laydown of the core inner barrel, and breaking of the catcher will be led by the coring engineer.
- Inner barrels must be laid out in 12-foot sections.

- If there are any sections of the inner core barrel not filled with core, these will be full of MOBM. The mud bucket must be attached to minimize mud spillage on the drillfloor during removal of these sections.
- The lower section of inner barrel is clamped and the inner tube alignment device is fitted to the inner tube above and below the joint.
- The joint in the 24-foot core assembly is threaded and unscrewed into 2 12-foot sections

9.2.8.3.3 Securing the inner barrel in the core cradle

A core cradle is not in the base-plan for transporting the MtElbert-01 core barrel assembly from rig-floor to pipeshed for disassembly. Core damage is not expected; however, if damage occurs during the initial core runs, the need for a core cradle will be reassessed and one may be constructed using pipe joints.

After removal from the core barrel assembly, the 2 12-foot inner barrels inside the 2 12 foot steel outer barrels must be quickly and safely transferred to the core trailer processing area using wooden boxes lined with absorbent material to contain any residual MOBM spillage. This provides a safe environment for the core processing team, and minimizes disruption to drilling operations. This must be done without allowing the inner barrel to bend.

9.2.8.3.4 Core Lay-down

No core cradle is needed for the core still in the inner barrel and the baseplan involves:

1. Using the rig crane or gently lowering the down the pipe skid (V-door) to transfer the core assembly from the rig floor to the pipeshed,
2. Extruding the core in the pipe shed and unthreading the assembly into 2 12-foot sections and ensuring proper PPE and containment of MOBM using absorbent materials and procedures,
3. Transfering the core to the core receiving trailer in wooden boxes supplied by ReedHycalog. Due to the weight involved and the difference in height of the pipeshed versus ground level, a fork-lift will be required to bring the inner barrels inside the steel outer barrels down to ground level.
4. Cutting the core inner barrels into 3 foot segments at inner barrel pre-cut tabs with pipe-cutters (this will occur in the Corion cold trailer, unless space requirements force a move into the Pipeshed for this operation).

- The safest way of laying down the core assembly and inner barrels will be decided by the team depending on the specific rig equipment, and will be outlined in the JSA for the activity.
- The best handling methods are is to be further determined by drilling rig personnel, BP Personnel and coring technician on location.

9.2.8.3.5 Laying Down Drill Pipe and the BHA (post wireline coring)

1. Hold a safety meeting with rig crews prior to laying down any tools to point out hazards and discuss safe operating practices.
2. Lay down the Corion Express drill pipe.

   a) The Corion Express drill pipe must have pin protectors on at any time the pipe is being lowered down the V-door onto the catwalk. Failure to follow these procedures could cause damage to the drill string.
   b) Pick up nubbins must be installed in the box end of each Corion Express drill pipe as well to ensure that no seal damage occurs.
   c) Repeat the above steps for the remaining drill pipe in the hole.

3. Lay down the Corion Express core collars.
   a) Lay down the core collars in the same manner as conventional drill collars using a lay down line or lay down machine.
   b) Ensure that protectors are attached to each core collar prior to laying them down the V-door.
4. Lay down the Corion Express core barrel.
   a) Set the core barrel in the slips with a collar clamp.
   b) Break the connections between the top stabilizer, the double pin seat sub and the core barrel.
   c) Remove the top stabilizer from the outer core barrel. Put the top stabilizer aside with protectors on it. Keep the pick up sub as it will be required again.
5. Remove the inner drilling assembly from the outer barrel.
   a) Attach the birdhouse clamp to the rope socket of the inner drilling assembly.
   b) Attach the rig’s winch line to the birdhouse clamp and lift the assembly upwards approximately 0.30m.
   c) Attach the pressure head clamp to the inner drilling assembly. Lower the assembly back into the outer barrel and have the pressure head clamp rest on the box end of the seat sub attached to the outer barrel.
   d) Remove the birdhouse clamp from the rig’s winch line. Attach the winch line to the pressure head clamp on top of the inner drilling assembly.
   e) Slowly raise the inner drilling assembly and remove it from the outer barrel in the table.
   f) Attach the wheeled cart to the bottom of the inner drilling assembly and lower it down the V-door onto the catwalk.
11. Attach the lifting sub and the 1’ spacing sub to the seat sub on the core barrel and hoist the barrel so the bit is out of the hole.
12. Attach the bit breaker and carefully remove the bit.
13. Attach the bottom protector to the core barrel and lay it down the same way as the Corion Express core collars.

9.2.9 SAGAVANIRKTOK FORMATION CORE PROCESSING AND SUBSAMPLING

9.2.9.1 Objectives

1. Rapid wellsite geological description for operational decisions.
2. Subsample gas hydrate-bearing time and temperature-dependent measurements and analyses.
3. Isolate the central portion of the core as soon as possible after coring in order to obtain samples with minimum (ideally zero) mud filtrate invasion and to minimize time-temperature dependent gas hydrate dissociation.
4. Seal and protect time and temperature-dependent samples so that they arrive at the laboratory for analysis in good condition.
5. Maintain core integrity to the extent possible by minimizing core transportation and by storing processed core together until bulk transportation is accomplished following the onsite core processing and subsampling program.

9.2.9.2 Safety

- All core handling presents a manual handling risk. Core handling operations will be carefully reviewed with the team, and all risks eliminated or minimized. Manual handling refresher training will be performed with the team before the first core is handled, and then will be refreshed as required.
- The core handling will involve cleaning the oil-based mud from the outside surface of the core. Proper PPE, wiping rags, and rag disposal must be followed to eliminate any environmental impacts of this operation.
- The inner core barrel tabs will be cut using a small abrasion saw; proper ppe and stand-off of core team must be followed during this operation.
- The core will be cut with chisel and hammer; proper ppe and precaution must be used to avoid rock chipping hazard and potential eye damage.
- Certain subsamples will be removed from the Corion processing trailer, marked with Styrofoam insert, and destroyed in the Core Press to obtain pore water samples. The Press operation, while simple, must be properly used and adequately cleaned between samples (since oil-based mud may be present in residual amounts, a proper solvent may be required to adequately clean the Press).
- Appropriate caution should be applied to the required compressed air line for the presses in the geo trailer. Note that if air line is needed to the cold trailer that it will not last very long in cold environment (i.e. pneumatic saw to cut inner barrel tabs). This issue will need to be worked out onsite.
- Appropriate caution should be applied to the required outdoor methane station and a nitrogen station near the core trailer. The methane and nitrogen bottles should be stabilized using a standard bottle rack assembly and protected from the elements by placing them on the leeward side of the trailer and possibly constructing a temporary shelter, if needed.
- Core barrels have tabs which require cutting using a small abrasion air saw which must only be used by qualified operators (suppliers) with appropriate personal protective equipment including gloves, goggles, dust mask and earplugs. All non-essential staff should stand clear.

A hot-work permit must be maintained for electrical equipment in the presence of potential out-gassing from hydrate dissociation of the core.

- Core processing is a non-routine activity. Pre-job briefings and training will be given to any staff who temporarily assist (e.g. rig crew, mudloggers).
- Team work hours will be monitored and a 12-hour shift system implemented. The baseplan is that no one should need to work longer than 12 hour days with a maximum of 16 hours. The baseplan for 24-foot core acquisition requires a 12 man team for processing within this framework (2 12-hour 6-man shifts) as documented in the below time estimate. This team of 12 is needed to maintain safe work hours for 2-3 days of successive 24 foot cores with approximately 90 minutes between cores. A 30-90 minute shift change-over time will be required during each shift change, depending on operations and difficulties.
- Core acquisition turn-around is expected to take 75 to 90 minutes per 24 foot core with the Corion system at optimum usage. Core processing and subsampling is estimated to require 60 minutes per 24 foot core.
- The planned MtElbert-01 core operation will be the longest yet in MPU experience with up to 600 feet of core (25 24-foot cores with full recovery). Change out of team members over the anticipated 2-3 day coring time will be managed to minimize loss of learning and impact of handover.
- A number of air-lines and power cables will be routed to the core processing area and these must be properly located and connected. They must not constitute a trip hazard.
- All core processing activities must be discussed with and approved by the BP Drilling Supervisor before work begins. Proper permits must be obtained for any specialized procedures and equipment. Proper BP authorization is required for special required equipment such as power saws, centrifuge, rock press, etc.
- There will be an outdoor methane and nitrogen station located near the cold core processing trailer for use in charging the methane and nitrogen pressure vessels containing selected subsamples of the core.

9.2.9.3 Core Handling and Processing

Core processing is to be managed primarily by the physical observation and description of the core, core mark-up, cutting into manageable lengths, geological subsampling and description, thermal and lmited pressure stabilization and preservation. There are a number of ways that the fluids contained in core could be altered by coring and core processing. These must be eliminated or accounted for to enable accurate Sw, Rw and hydrocarbon geochemistry data to be obtained from core extracts. The wellsite sampling plan and additional core processing information is presented in-detail in Appendix A. Appendix B contains onsite form templates for use in sample logging procedures. Appendix C documents BP HSE and PPE general requirements.

9.2.9.3.1 Core Receiving in the Corion Core Trailer (5 minutes):

- Arrival of core through small service door
- Pick up core and move to trays
- Position at end of core trays

- Use pipe-cutters to cut slotted 12-foot liners into 3-foot lengths (if space is too tight in the core processing trailer to achieve these cuts, then this operation may need to take place in a very cold area of the pipeshed, perhaps near the door)
- Clip tabs on split liner (small abrasion saw)
- Lay out full length and initial inspection
- Wipe off and clean and mark core (left, right, mark each 3 foot increment)

9.2.9.3.2 Core Logging (10 minutes):

- Measurements (tape from the top core).
- Position marker (index) card at top depth in decimal feet using tape along side core.
- Record sample depths on master clip-board form.
- Sample depths will be marked and recorded in decimal feet.
- Cleave core to match pre-cut foam inserts for subsampling requirements.
- The core will be slid in the core tray to remove any small gaps in the core; however, any large voids will be filled with labeled foam fillers.
- Quick scrape (rubber squeegee) and Identification: Gas hydrate occurrence, physical properties, gross sedimentology and structural geology. Information enter onto standard form with sand, grain-size, grading, etc.).
- Install thermometers (about four hand-held digital type) and record temperatures in degrees F; note difficulty to insert into hydrate-bearing sand; install in pre-cleaved area, if possible (OMNI).
- Pull core data P-T logger (Temperature Rabbit) and replace if needed (OMNI) and return to Corion for next core run.
- Core shift supervisor cuts each subsample required with hammer and chisel.
- Move sample to designated sample work area (micro-biological, etc.)

9.2.9.3.3 Supplemental Core Logging (as time permits):

- Conduct Thermal IR (skate mounted system and hand held camera); 3 minutes (if IR Camera available); OMNI
- GR core scan with skate system (ad hoc core scans); 3-5 minutes; OMNI.
- Plain light photo imaging (ad hoc core photos), two digital cameras (10 Gb and 6.2 Gb system). Images will consist of standard core images and image logs of samples taken from the core; 2 minutes; Geochemist/Physical Properties.
- Digital (DVD) video camera scans (ad hoc scans), most hand held, skate system being considered. Images will consist of standard core images and image logs of samples taken from the core; 2 minutes; Geochemist/Physical Properties.

9.2.9.3.4 Gas Hydrate Core Sampling (10 minutes):

- Quick gas hydrate dissociation test. Small pieces of core – typically core edge-chips (2-4 samples per core), 3 different systems: (1) volume yield in water (2 gallon igloo cooler to insulate water from freezing), (2) syringe system – most proven (2-5cc in 100ml syringe;

place by core), and (3) small pressure vessel (rare samples, large chunks of gas hydrate only); concurrent activity.

- Gas hydrate samples (noted best by visual observation of bubbling core); whole-round-core (WRC) samples from apparent gas-hydrate-bearing sections (20 plus per project), to be stored in (1) liquid nitrogen and/or (2) Parr pressure vessels; concurrent activity. Pre-cut foam inserts available. Approximately 30 vessels will be available; may not use up to ½ of these, depending on quality of core available. Samples will remain frozen. Physical Property representative with OMNI observer needed during pressurization outside at methane and/or nitrogen station outside of core trailer. Vessels will be stored in wooden box and transferred to refrigerated truck storage area onsite.
- Sheet of paper for logging samples is on clipboard mounted on wall with correct pre-cut lengths for required subsamples and subsample shorthand codes will be discussed during onsite dry-runs.

9.2.9.3.5 General Whole Round Core (WRC) Sampling (10 minutes):

- Head space gas samples, WRC samples (3-4 WRC samples per core placed in quart size cans; 31 quart cans will be available; 120 pint cans available), sampled as directed, from reservoir sand and shale sections, samples should be and remain frozen; will transport in igloo coolers; concurrent activity.
- Microbiological samples, WRC samples in bag, partial heat-seal, seal with nitrogen (approximately 2 samples per core); duplicate sample directly tied to every-other head-space gas sample; Spacing will be determined; concurrent activity.
- Pore water sampling for field processing, WRC samples (3-4 WRC samples per core placed in air tight sample glove bags; blow open bag using nitrogen, then insert sample), sampled as directed, from reservoir sand and shale sections, samples should not be frozen and are transferred to warm trailer for sampling; concurrent activity.
- Physical properties (MAD and grain size analysis), single WRC samples (4-6 WRC samples after clean-up edges to avoid contamination per core), for grain density analysis, sampled as directed, from reservoir sand and shale sections, samples should not be frozen; concurrent activity.
- Physical properties (geotechnical and strength testing), a total of about 10 WRC samples for the entire well, sampled as directed, from reservoir sand and shale sections, samples will be both frozen and non-frozen; wrapped in foil and plastic wrap and placed in zip-lock or OMNI 3 foot zip-lock (if available) bags; concurrent activity.
- Petrophysical properties (intrinsic porosity-permeability studies, no gas hydrate phase), a total of about 20 WRC samples for the entire well, sampled as directed, from reservoir sand and shale sections, samples should be frozen; concurrent activity.
- An OMNI representative will bag small chips from the top faces of each 1-foot core as taken by shift-team lead length as required by the State of Alaska.

9.2.9.3.6 Core Processing for Water Analyses (Warm Trailer, Concurrent Activity)

Certain subsamples will be removed from the Corion processing trailer and marked with Styrofoam insert labeled IW. These samples will be destroyed during squeezing using a hydraulic press to obtain pore water samples. While obtaining pore fluids is a simple operation, samples must be properly handled to avoid contamination and oxidation of some chemical species, and the squeeaers must be adequately cleaned between samples to avoid cross sample contamination or interference by small amounts of oil-based mud that may be present.

- Store WRC in glove bag while waiting to be squeezed
- Clean WRC to remove outer layer contamination
- Examine and describe sample
- Take sub-sample for grain size (Winters)
- Load the rest on squeezer
- Press and collect the water on syringe (10 or 30 cc, depends on expected volume)
- Filter again through a 2 um acrudisk (on line filter)
- Take a salinity reading using refractometer and record in logbook
- Take a Rw measurement using the probe and procedures provided by OMNI
- Record total volume of water collected

Subsample pore water:

- 2 ml in 4-ml glass vials glass vial for NH_4 analyses, fozen
- 1 ml for sulfate analyses in 2 ml-microcentrifuge tubes pre spiked with $CdNO_3$- residue for sulfide work
- 3 to 10 ml for halogens in glass vials (4 or 20 ml).
- 2 ml in agilent vials for $\delta^{13}C$, preserved with $HgCl_2$
- 2 ml in agilent vials for $\delta^{13}C$, frozen (in case the $HgCl_2$ results in salting out effects due to low salinity of the fluids)
- 2 ml in glass vials for acetate, frozen (for Lorenson)
- 2 ml in agilent vials for D/O- no treatment
- The rest in 8 ml nalgene bottles for major and minor analyses

Squeeze cakes

- Store and seal in plastic bags
- Clean and dry squeezer for next sample

Drill fluid contamination

- Sample and process drill fluid sample and cuttings in a regular basis

Drill fluid and sediment disposal

- Drilling fluid and core that is uncontaminated by water or chemicals can be recycled in drilling fluids on the rig
- Proper site disposal of other materials must be achieved

9.2.9.3.7 Thermal-Properties Whole Round Core (WRC) Experiment (15 minutes):

3" to 6" long whole, round core samples will be received in insulated containers and placed into a cooler for sample preservation. The core will be pushed through the container; sheared off to expose a new clean, flat surface (likely core-end at center or scrapped core to flat, clean surface); the surface irregularities will be removed; and then the thermal properties will be analyzed. Thermal property measurements will be made by pressing the thermal property probe against the smoothed hydrate surface. Each measurement will take on the order of 30 seconds. For each core sample that it received, this measurement process will be repeated at approximately every inch. Efforts will be made to conserve core material by combining this WRC with water analyses and/or physical properties subsampling. Likely 1 sample per core, some gas hydrate-bearing, others non-hydrate-bearing.

Equipment used for this analyses will include: Laptop computer; Agilent E364A Dual Output DC Power Supply; National Instruments cDAQ-9172, compact data acquisition chassis; Sensor assembly and circuitry, including insulated resistor; Basic tools for assembly and multi-meter; and Core sample holders and ice chest for sample receiving/holding/preserving.

9.2.9.3.8 Core Archiving and Storage (10 minutes):

- Gaps left by removing core samples will be filled with sample labeled foam fillers.
- Plastic wrap core and reposition core linearly into the previously cut 3-foot sections.
- Place end caps, seal with tape (end caps and split down the linear) and label.
- Store (freeze cores); 2 OMNI representatives will carry 3-foot sample (20-30 pounds) to onsite refrigerated truck; Pressure (Parr) and liquid nitrogen vessels will also be stored in this truck. 3-Foot tube will be stored in 3-foot card-board box (if space available) and into 4X4 container with Styrofoam inserts for shock protection (80 to 100 3-foot boxes in 1 4X4 container).
- Gas monitor and ventilation will be placed appropriately in refrigerated truck and visible prior to entry to truck (to be installed by ASRC Energy Services O&M group into Carlile truck). Access to truck will be controlled via secure entry (key or other). Arctic Gear and anti-slip wear on ice; anti-slip wear must be removed at entry to truck; may alternatively require receiving crew inside truck. If OMNI staff needed for second core, may require different group to handle the core storage if causing delay between cores.

9.2.9.3.9 Other Non-Core Related Samples (no impact on coring):

- Gas samples, canned drilling cuttings taken by mud loggers, from spud to TD.
- Flowed gas samples, collected in aerosol cans by the mud loggers.
- Also isotubes and ARMIS sample cylinders

9.2.9.3.10 Core Processing Equipment and Supplies

Detailed core processing equipment and supplies lists are available by vendor.

9.2.9.3.10.1 Core Processing Equipment - Core Gamma Logger

- Core gamma logger and all ancillary equipment and spares.

9.2.9.3.10.2 Core Processing Equipment - Core measuring and marking

Rags for cleaning inner barrel, solvent for erasing marking errors, paint pens that will indelibly mark inner barrel under rigsite conditions, good quality steel tape measure greater than 30-ft long.

9.2.9.3.10.3 Core Processing Equipment – Core barrel slotted liner tab Cutting Saw

- The saw must be designed to present minimum risk to the operator and core team (flying objects, dust, noise, manual handling).
- The saw must be capable of cutting through the inner barrel tabs in the slotted liner and the core safely in one pass with minimal vibration.
- The saw blade must be adequately guarded.
- Saw blades must be intrinsically safe, composite silicon carbide blades are not recommended as these can explode during use.
- Only the approved staff may operate the saw, and they must wear appropriate personal protective equipment at all times. Only essential core processing staff will be allowed in the area, which will be taped-off.
- Spare saw blades must be supplied.
- Core must be cut without causing any contamination or damage that would compromise core analysis objectives.

9.2.9.3.10.4 Core Processing Equipment – Core barrel slotted liner Pipe-Cutters

- Care should be taken to cut the slotted inner barrel into 3-foot lengths, typically at a solid tab location.

9.2.9.3.10.5 Core Processing Equipment – End-caps, clips and tools

- Equipment used to protect core faces.
- Secured with hose clips. The supplier is to ensure that clips are correct size, in good condition and corrosion free (spray with light oil before dispatch).
- Coring company to supply good quality pneumatic or electric "screwdriver" (+ 1 spare) to secure caps and clips.
- 2 x caps and 2 clips required per cut section. Approximately 4 caps and 4 clips should be available for each 3-foot core section (including those for temporary capping of samples awaiting preservation).

9.2.9.3.10.6 Core Processing Equipment - Core Racks

- Racks sufficient to hold multiple 3-foot sections of core to be provided (OMNI 4X4 containers)
- Racks will be designed to minimize the opportunity for manual handling injuries.

9.2.9.3.10.7 Core Processing Equipment - Core Sampling for Geological Inspection and Subsample site selections

- Sealable sample bags and sampling equipment (spoon for soft sandstone and hammer and screwdriver or small chisel for hard sections). Paint scraper and spatulas for cleaning core faces for inspection
- Sampling lists and box logs.
- Any other specialized geological sample description equipment required.

9.2.10 BULK CORE PRESERVATION BY FREEZING

9.2.10.1 Objectives

1. To ensure that the remaining (non-subsampled) core is preserved by freezing to provide a flexible and unbiased sample of all rocktypes cored for future conventional and special core analysis requirements.
2. To ensure that all preserved core is sealed, supported and later packaged so that it arrives at the laboratory without drying, contamination or structural damage and in good condition for special core studies.
3. To ensure that all preserved core remains in suitable condition for analysis for a significant length of time (sufficient to support all anticipated appraisal requirements).

9.2.10.2 Safety

- Standard electrical equipment will be used during core processing so hot - work permits must be raised and precautions observed.

9.2.10.3 Core Preservation by Freezing

- 3-foot sections of remaining core and spacer material are plastic-wrapped and stored in onsite refrigerated truck in OMNI 4X4 containers until completion of coring and preparation for transport to Anchorage.
- Although the technique is straightforward to apply, it is particularly susceptible to poor quality control, both in experimental procedure and technique. The initial handling and wrapping of soft or friable sections will require special care.

9.2.11 CORE TRANSPORTATION

9.2.11.1 Objectives

1. To ensure that the core samples all arrive at the Anchorage site storage by DOT-approved containers in the shortest cost-effective time without loss or damage with full chain-of-custody handled by OMNI Lab staff.
2. To ensure that good communications exist at all times between handling agents.
3. To ensure that the core is transferred to the Anchorage core storage refrigerated trailer by the shortest transit route and that all shipping contributors are briefed on the need for careful core handling to prevent damage.
4. Carlile refrigerated truck setup to provide onsite storage (leave diesel truck running and fueled); this will require Milne fueler to come onto ice-pad daily. Once coring completed, this

truck will be used to transport bulk core, Parr, and nitrogen vessels, head-space gas, and frozen samples to Anchorage storage refrigerated trailer facility at ASRC Yard. Shipping documentation is signed off onsite and will involve identification of hazardous materials.

5. Regarding ventilation in the storage/transport container, BP will require no gas buildup either during onsite storage or during transport. As such, BP will require continuous monitoring both onsite and during transportation. This will require a remote monitor that is capable of being monitored and not require manual inspection during transportation.
6. It is the BP ADW and HSE position that we can not store material onsite or approve transport without these measures in place. If this is not able to be accomplished, it will remain ADW's decision to delay coring or not core until proper storage and transportation requirements are met.
7. Alternative onsite storage options may include open-air storage (Flatbed truck) until monitoring and ventilation requirements can be met.
8. There will be a clearly established accountable party(ies) for the core transportation truck. Along with proper ventilation and monitoring the process for hauling the core through the field and then down the road will be clearly understood with clear chain-of-custody requirements.

9.2.11.2 Safety

- Heavy lifting procedures must be followed when moving core boxes and equipment.
- All core and equipment must be securely loaded into containers to prevent shifting during transit which could damage the core and endanger onshore handlers.

9.2.11.3 Operational details

The stabilization and freeze-preservation techniques used to protect the core will reduce sensitivity to mechanical shock, however it is essential that all of the people involved with core handling be briefed as to the fragile nature of the core. The following are some of general guidelines, though transportation is always location specific and a set of procedures should be agreed for the coring operation.

9.2.11.3.1 Transport from rig to Anchorage storage facility

Mt Elbert Shipping Summary:

1. Return equipment shipments to the various science labs. Recommend using Alaska Airlines through Tool Services.

2. Bulk frozen core shipment to Anchorage. All of the bulk frozen core will be transported in a refrigerated truck (temperature -10 deg C) to the "frozen" core storage facility in Anchorage (under development within this project). It is assumed that these cores will be stored at the drill site in the same refrigerated truck to be used for shipping to Anchorage. Omni will be responsible for this shipment.

3. Frozen subsamples will be shipped with the bulk frozen core to Anchorage (Omni control). These samples will subsequently be sent to Lower-48 labs in dry-ice shippers through World

Courier as our climate controlled shipping company. We need to work on the Omni to World Courier hand off. Dry ice temperatures (-78 C) with the P samples may require further thought - can we keep them at a higher temperature, but still ensure they stay frozen?

4. Subsamples that cannot be frozen (i.e., pore waters samples, and some WRC samples etc.), must be shipped by air or ground under climate controlled conditions, keeping the samples cold but not frozen. Probably be best to ship directly from the Slope to the Lower-48. We need to identify the responsible parties and shipping process for this sample type. This would perhaps apply to fine-grained consol and strength samples but not coarse-grained samples.

5. Liquid nitrogen shippers will be shipped with the bulk frozen core to Anchorage (Omni control). These samples will be sent to Lower-48 labs in the LN2 shippers through World Courier as our climate controlled shipping company. We need to work on the Omni to World Courier hand off.

6. Pressure vessels will be shipped with the bulk frozen core to Anchorage (Omni control). These samples will be sent to Lower-48 labs in through World Courier as our climate controlled shipping company. We need to work on the Omni to World Courier hand off. Hazardous shipment, compressed methane gas (about 800 psi) will be used to pressurize the samples. World Courier should have an office in Anchorage.

7. The Anchorage storage facility will be fitted with gas and power-off monitors/alarms

- The core-shift lead geologists, logistics team and core specialist should review this model. The agreed transportation route should be secure, should minimize handling steps and maintain freezing temperature.
- All individual core boxes should be braced into 4X4 OMNI shipping containers for transport to Anchorage. Each crate or box should be clearly labeled with the well number and sample number on the lid and ends of the boxes.
- All communications regarding the core shipment should be channeled through the core shift lead geologists (ASRC, USGS, DOE).
- All communications should make it very clear that the core is fragile, and request gentle handling.
- The core specialist or BP Operations Geologist or core shift lead geologists (ASRC, USGS, DOE) should brief all of the rigsite and local core handling teams.
- The BP Operations Geologist or one of the core shift lead geologists (ASRC, USGS, DOE) must witness offloading of core containers to transport vessels and request gentle handling at all stages.
- An Operations Geologist or OMNI representative must meet the core at Anchorage storage facility at the ASRC Yard and witness offloading.

9.2.11.3.2 Core Processing

Core slabbing will occur at a later date at the Anchorage core storage facility.

9.2.11.3.3 Subsequent core transport for special studies

- Customs requirements must be checked for core that will have to leave the country, if it is likely it will be required to open individual core pieces, then some means of re-sealing the core before drying can occur should be available.
- The flight details and airway bill number and a copy of the airway bill must be transmitted to recipients in advance of shipment.
- An inventory of the core should accompany all shipments. A separate copy of this inventory should be sent to recipients via Fax or email with an estimated time of arrival.
- Transport of oil and gas samples (including core samples containing hydrocarbons) by commercial airfreight must be carried out in accordance with special procedures. Only specially trained personnel may perform these duties and sign the official declarations. All core samples must therefore be packaged in accordance with the IATA "Dangerous Goods Regulations Manual".
- Direct flights should be used to minimize unsupervised core handling.
- With international airfreight transportation, the storage cabin may not be pressurized. The associated temperature and pressure changes can have an adverse effect on the integrity of the applied core preservation. It is therefore recommended that aircraft with pressurized holds be used for transporting preserved core samples. Commercial carriers, which are unaccustomed to transporting fragile materials, should not be used, or used with caution.
- Below freezing temperatures should be maintained at all times by shipping in freezer containers or dry-ice.

9.2.12 ADDITIONAL CORE SUBSAMPLING PROGRAM DETAIL

Hole TD: permitted to 4,000 feet TVDss, Operational TD expected at 3,000 feet TVDss
Core point: approximately 2,000 feet TVDss
Core interval: approximately 2,000-2,600 feet TVDss. Expect to core interval of 400-600 feet in about 2-3 days; advance the hole about 200 ft per day.
Primary core target: two-three 25-to-75-ft-thick gas-hydrate-saturated sandstone sections, located above the base of the gas hydrate stability zone. No free-gas-bearing sections expected either in or below that base of the gas hydrate stability zone which is predicted to be at a depth of about 2,853 ft (TVD). Free gas is not expected, but remains a possibility.

Environmental monitoring and HSE: the primary monitoring issues deal with flammable gas, or potential oxygen depletion. BP HSE will supply monitoring equipment for the Corion trailer (and other lab units, if needed). JRA’s will address monitor and hotwork protocols. While processing a core we would recommend leaving the side access door partially open to promote air circulation and to keep the lab space cold.

Oil-Based Mud: Maintain containment of OBM fluids and use proper PPE and absorbent materials. Wipe off and clean core assemblies and core. Take special precautions to handle the core from the drill floor to the trailer to prevent any spillage. Appropriate disposal containers will be provided

.

Additional Core Processing Procedures, Logging, and Core Cleaning:

-Measurements- assume top is top, tape from the top of the run to avoid measurement errors

-Position marker card at top depth in cm units – per OMNI procedure. All depths are taped from the marker by adding on tape measure length.

-The core will be slid in the core tray to remove any small gaps in the core; however, any large voids will be filled with labeled foam fillers.

-Quick scrape and Identification: Gas hydrate occurrence, physical properties, gross sedimentology and structural geology. Information enter onto standard form (Attachment 1 – quick core notes from Mallik-format).

-Install thermometers (hand held digital type with large numbers, provided by Omni) and conduct Thermal IR (hand held camera, provided by DOE through BPXA) measurements. The hand held IR imaging procedures will need to be developed and tested for a cold room environment; this technology has not been used under these conditions. We will not use a complex IR core scanning program, this type of operation requires a standalone computer system and track driven system. We will move ahead with a handheld approach with images being stored on internal memory cards. We should also work with Omni to develop a skate mounted systems with wheels that could be pulled down the core layout table to scan parts of the core. The two project IR cameras will be supplied the USDOE on loan to BPXA. Bob Hunter will need to arrange this loan through Ray Boswell- valued at ~$65K each – used in India, returned by Tim to College Station.

-Set up and complete plain light photo imaging. Two digital cameras (10 Gb and 6.2 Gb system), along with portable lights, copy stand, tripod, and system computer for still photography work. The USGS will provide all of the listed photo equipment. Photo images will be taken on an ad hoc basis and not as complete core scans. Images will consist of standard core images and image logs of samples taken from the core.

-Setup and have available digital (DVD) video camera system, to be provided by the USGS. Work with Omni to mount video camera on a skate system like the IR – but this may be time-intensive &/or too complex for operation? – not sure what skates would ride on for this? Modify GR skate to hole IR and could it also hold a video?

-Setup and complete GR scan. We need Omni – YES- to supply us with operational description and recommendations on how to integrate the GR scans into the proposed core flow work plan.

-Pull core data P-T logger and replace if needed. P-T system to be provided by Corion.

Core Sampling and Measurements:

I. Quick gas hydrate dissociation test. Small pieces of core – typically core edge-chips (2-5 cc) thought to contain gas hydrate as selected by the core logger. No more than 1-2 samples per meter of core. 3 different systems:

1. Volume yield in water (system provided by USGS); but bubbling of gas through water affects CO2 isotopes
2. Syringes (system provided by USGS) – 200cc syringes – best approach, valve w/ handpump to vacuum – get high-quality gas and water sample from this and pseudo-volumetric calculation – also better as quick, simple, easily able to monitor

3. Small Pressure vessel (system provided by USGS) – a bit more elaborate, do not typically use this as consume too much core

II. Gas hydrate samples; whole-round-core (WRC) samples from apparent gas-hydrate-bearing sections, to be stored in:

1. liquid nitrogen shippers (WRC lengths 12cm or 25 cm long), 25cm long cups, wrapped in Al foil, put in cloth bags, and labeled
2. DOT approved Parr pressure vessels (25 cm long). See more details below on gas hydrate samples. However, if the gas hydrate rich samples are recovered frozen these samples should be kept frozen.

III. General whole round core (WRC) samples and core catcher (sample frequency, size, and storage considerations noted)

1. Head space gas samples, WRC samples collected in quart size (core drops right into can) paint cans with salt used as preservative (just like cuttings procedure), sample as directed, from reservoir sand and shale sections, supplies and procedures to be provided by the USGS. Samples should be frozen.
2. Pore Water Sampling for later analyses – We need to review with Omni what is the standard industry procedures used to sample and analyze core derived pore-waters with oil based drilling fluids. The Mallik 2002 effort represented a mixed program, being ran mostly by research chemist with little to no background in petroleum issues. But the results reviewed in the Matsumoto et al paper look very good. This is very time sensitive and must be done onsite – if waters stay in contact with core, the water will become altered. Thus, based on the Mallik 2002 and marine research programs, we propose the following program: Sample 10-cm-long section of WRC, about every 1-2 meters, the outer 2cm of the core should be removed and the sample stored in sealed gas-tight plastic bags, not frozen, and transported to the field lab. The sample will be squeezed in a Manheim-type press (supplied by the USGS) – Alternative approach to centrifuge – this has not been as effective. The extracted water is filtered and stored in glass vials, then shipped to an appropriate laboratory for the following future analysis: Cl-, SO4, Na, K, Ca, Mg, Sr and Ba.
3. Physical properties (MAD), WRC samples (about 10cc of core) for grain density analysis, sample about every 0.5-1.0 meter or as directed, from both reservoir sand and shale sections. Additional 40g of WRC sample for grain size analysis closely associated with MAD WRC samples. Required supplies and procedures to be provided by the USGS. Samples should NOT be frozen (refrigerated only). All MAD and grain size analysis will be done post field, thus limiting the laboratory requirements in support of theses analysis. Bill Winters, USGS, did this procedure at Mallik after the core was frozen. We could do a small number of subsamples at well site and more samples later, but we would prefer to collect all of the subsamples at the well site under refrigeration storage.
4. Physical properties (geotechnical): (long pieces of core, but few samples)
    - -20 cm long whole-round samples for consolidation and index properties. A total of about 6-8 samples (for entire cored section) from the major representative lithologies. Required supplies and procedures to be provided by the USGS. Samples should NOT be frozen. However, if the gas hydrate rich samples are recovered frozen these samples should be kept frozen.

-50 cm long whole round samples for strength testing. Both coarse and fine-grained textures are needed for comparison. A total of about 6-8 samples from the major representative lithologies. Required supplies and procedures to be provided by the USGS. Samples should NOT be frozen. However, if the gas hydrate rich samples are recovered frozen these samples should be kept frozen.

5. Physical properties (thermal conductivity), we have evaluated our experience with the Mallik 1998 and 2002 efforts. We have also consulted with the GSC and we are now recommending not making any thermal conductivity measurements because of the disturbed condition of the core material and the metastable condition of the cores if gas hydrate bearing.
6. Physical properties (Vp, Vs, impedance, resistivity). Need to evaluate how practical it is to move ahead with these measurements in the cores we will be dealing with. Nice with multi-sensor track system, but with any gas in core, these measurements could be very difficult. Systems in-place work better with consistent marine sections. (NOTE that Anadarko burned up a lot of surface time taking these measurements on Hot Ice well. We have evaluated our experience with the Mallik 1998 and 2002 efforts; we have also consulted with the GSC and we are now recommending not making any Vp, Vs, impedance, resistivity measurements because of the disturbed condition of the core material and the metastable condition of the cores if gas hydrate bearing. However, these measurements will be made on the pressure vessel subsamples that go to GHASTLI in Woods Hole (USGS).
7. Petrophysical properties (intrinsic porosity-permeability studies, no gas hydrate phase), WORKING? Need to evaluate potential service providers. Bill Winters will review old Core Labs proposal from the Mallik 2002 effort. Do MDT and NMR and send samples to reconstitute hydrate phase. Can OMNI freeze core and analyze this system under triaxial loading conditions – basically a dual-porosity system measurement. Please see email from Collett to Winters dated November 13, 2006 on this topic – we are waiting for a modified proposal from Core Labs and review by OMNI.
8. Microbiology (cell counts and/or culturing). Tim Collett has contacted Rick Colwell (ex-INNEL, now at Oregon University) for his recommendations. Source of gas, active microbes, processes, petroleum system (Eileen trend may be much more open system than Mallik). This is very temperature-dependent; if freeze samples, becomes a cell count issue. If remain near-in-situ temperatures, store with Nitrogen in bags and microbe continues to live. Only need 6-12 samples, 2-4 cm of core – should take 2X this and freeze half?

Gaps left by removing core samples will be filled with sample labeled foam fillers.

Core diagram or photos of samples to be taken (and when); what is consumed in sampling.

IV. Other Samples:

1. Gas samples, canned drilling cuttings taken by mud loggers, from spud to TD, at 9 meters spacing, supplies and procedures to be provided by the USGS.

2. Flowed gas samples, collected in aerosol cans by the mud loggers, from a splice in the gas trap line, as directed during significant gas flows, supplies and procedures to be provided by the USGS.
3. Also isotubes and ARMIS

Whole Core storage (90-95% remaining core):

-pipe-cutter 3-foot intervals within inner core barrel liners
-place plastic wrap
-place end caps
-seal with tape
-store (freeze cores)

Core Transportation:

-All of the bulk frozen core will be transported in a refrigerated truck (temperature -10 deg C) to the “frozen” core storage facility in Anchorage. It is assumed that these cores will be stored at the drill site in the same refrigerated truck to be used for shipping to Anchorage.
- If have cargo-only plane, should be able to legally ship without a problem for non-pressurized core
- For pressurized core with methane used for pressurizing, could also ship via plane in approved DOT containers (could also use refrig truck)
-The subsamples that will be frozen can be shipped with the bulk frozen core to Anchorage and/or Fairbanks; these samples can be sent to Lower-48 labs in dry-ice shippers. Historically we have used World Courier as our climate controlled shipping company.
-The subsamples that cannot be frozen (i.e., pore waters samples, etc.), must be shipped by air or ground under climate controlled conditions, keeping the samples cold but not frozen.
-The Liquid N2 shippers can be shipped by either land or by air (DOT approved). However, we would also recommend that these samples be transported to Anchorage and/or Fairbanks with the bulk frozen core shipment; these samples can be sent to Lower-48 labs via air service. Historically we have used World Courier as our climate controlled shipping company.
-The physical property samples stored in the DOT approved Parr pressure vessels are the most difficult samples to deal with. They will be pressurized to about 800 psi with flammable methane gas, these samples cannot be frozen, but the temperature can not exceed about 10 deg C. We would recommend that the Parr pressure vessels be transported to Anchorage and/or Fairbanks in a dedicated climate control vehicle. Note that these vessels can be shipped on aircraft under these conditions. Historically we have used World Courier as our climate controlled and hazardous shipping company.

Post Field-Core Studies:

-Under Development
-Detailed core descriptions
-Quantitative mineralogy
-Paleontologic analysis

Core Samples – ADDITIONAL NOTES

Gas Hydrate Samples:

Liquid Nitrogen Samples- LN2

5 Dry shippers
Capacity 7.75m or 35 of the 25-cm-long samples
Our plan is to inventory a representative suite of samples (12-cm-long samples wrapped in Al-foil placed in cloth sample bags). The USGS will be able to supply two of the appropriate shippers. Recommend the following shippers and supplier: Chart Industry DOBLE 11498684, www.clubcalves.com, $1050 per shipper. We will also need to identify a source of Liquid N2 on ANS. May need special filler hose depending on source.

Pressure Vessel Samples

Total of 20 Parr (DOT approved) gas hydrate shippers
20-cm-long vessels, to be filled on site and pressurized with methane gas to about 800 psi, and maintained at temperatures above freezing in the range of 5-10 deg C (4 meter of core). Bob Hunter will need to borrow the 20 Parr vessels from Chevron/DOE JIP through Ray Boswell. Will also need to identify a source of laboratory methane (with limited impurities, 99.9% methane) on the ANS - ? if available at Prudhoe lab facility??.

Gas Samples:

-Canned drill cuttings: The contract mud logging company collected and canned drilling cuttings as specified: With cuttings being collected at 30 foot spacing from about 1900 feet TVDss to TD. The canned drill cuttings should be treated with an extra heavy dose of table salt and frozen for most of their life.
-Flowed gas samples: The contract mud logging company should also collect flowed free gas samples from the mud trap installed in the drill mud return tank on the shaker table (near the location where the canned drill cuttings were collected).
-Canned WRC: As directed by core shift manager. This sample set is the most important gas geochemistry sample set to be collected. The weight of can and core samples should be recorded. Each sample should have a 200 ml headspace drawn down on the can before closing.
-Quick gas hydrate syringe samples: As directed by core shift manager. These samples include in most cases one or more gas samples in 30ml glass bottles and a bag containing both the total volume sediments and water from which the gas sample evolved. Record derived gas volume on sample log sheet. The associated bag samples should contain all of the sediments and water, which was removed from the syringes after the gas hydrates were disassociated.
-MDT gas and water samples: WORKING?

Water Samples:

-Field laboratory: Squeezed water samples will be immediately analyzed for salinity, alkalinity, and ammonium, and sulfide will be precipitated in order to subsequently (lab-based) obtain correct sulfate and sulfide concentrations. [See above description about all analysis post field]

-Lab-based analyses will consist of the following major, minor, and trace components:
  - -Majors: Cl, Na, K, Ca, and Mg concentrations;
  - -Minors and traces: Sr, Br, Fe, I, Ba and Mn concentrations
  - -Dissolved inorganic carbon (DIC) will be analyzed for d13C values

-MDT gas and water samples – this needs to be coordinated with Schlumberger

Physical Properties Samples:

-Goals of the program:
  - -Constrain baseline index and grain-size properties of host sediment
  - -Relate index properties to gas hydrate occurrence (need profile of S_h from logs)
  - -Determine stress history and relate to sedimentology
  - -Determine strength and other parameters needed by modelers for prediction of behavior during production

-Samples needed to accomplish above goals
  - -10cc WC/grain density samples every m or less and at transitions in texture, boundaries, BGHS. (Handling protocol of these samples will be especially important because of the potential for drainage in coarse-grained sediment).
  - -About 40g(??) companion grain size samples for #1 above.
  - -20 cm long whole-round samples for consolidation and index properties.
  - -50 cm long whole round samples for strength testing. Both coarse and fine-grained textures are needed for comparison.