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

September 2003 Quarterly Technical Report
Third Quarterly Report: July 2003 – September 2003
Cooperative Agreement Award Number DE-FC-01NT41332

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ABSTRACT

Interim results are presented from the project designed to characterize, quantify, and determine the commercial feasibility of Alaska North Slope (ANS) gas-hydrate and associated free-gas resources in the Prudhoe Bay Unit (PBU), Kuparuk River Unit (KRU), and Milne Point Unit (MPU) areas. This collaborative research will provide practical input to reservoir and economic models, determine the technical feasibility of gas hydrate production, and influence future development, field extension, and exploration of this potential ANS resource.

The large magnitude of unconventional in-place gas (40 – 100 TCF) and conventional ANS gas commercialization evaluation creates industry-DOE alignment to assess this potential resource. This region uniquely combines known gas hydrate presence and existing production infrastructure. Many technical, economical, environmental, and safety issues require resolution before enabling gas hydrate commercial production.

ANS gas hydrate and associated free gas reservoirs are being studied to determine reservoir extent, stratigraphy, structure, continuity, quality, variability, and geophysical and petrophysical property distribution. Phase 1 (October 2002 – October 2004) is characterizing reservoirs and fluids, leading to recoverable reserve and commercial potential estimates, and defining procedures for gas hydrate drilling, data acquisition, completion, and production. Phases 2 (October 2004 – October 2005) and 3 (October 2005 – October 2006) will integrate well, core, log, and production test data from additional wells, if justified by results from prior phases. The research program could lead to future ANS gas hydrate pilot development.

This project will help solve technical and economic issues to enable government and industry to make informed decisions regarding the resource potential of unconventional gas hydrate accumulations. As this project enters into the second year of the 2-year Phase 1 research program, reservoir and fluid characterization within the Eileen trend area indicates significant stratigraphic and structural heterogeneity, causing compartmentalization of the gas hydrate accumulations. These interim research results highlight the importance of the resource characterization phase before any production testing might occur. Describing reservoir and fluid compartmentalization will help choose the best testing site for potential phase 2 operations.

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2.0 INTRODUCTION

This project is helping to solve the technical and economic issues to enable government and industry to make informed decisions regarding potential future commercialization of unconventional gas-hydrate resources. The project is characterizing and quantifying in-place and recoverable gas-hydrate and associated free-gas resources initially in the Eileen trend area in the Prudhoe Bay Unit (PBU) – Kuparuk River Unit (KRU) – Milne Point Unit (MPU) areas on the Alaska North Slope (ANS). The project is also investigating gas hydrate phase equilibrium and relative permeability within porous media. Additional laboratory investigations include design of best practices for drilling, completion, and production operations within gas hydrate-bearing reservoirs.

Successful determination of the resource potential of gas hydrate and associated free gas resources could significantly increase current developable gas reserves available for reservoir energy support, secondary recovery, fuel gas, and commercial sales within and beyond current infrastructure on the North Slope of Alaska. Proving technical production feasibility and commerciality of this unconventional gas resource could lead to greater energy independence for the U.S., providing for future gas needs through an abundant, safe, secure, and stable domestic resource.

2.1 Project Open Items

Through September 30, 2003, DOE has obligated approximately 90% of Phase 1 research funds. BPXA currently accesses these project funds through the U.S. Treasury Department Automated Standard Application for Payments (ASAP) system in accordance with 10 CFR 600.122(b). As first indicated in the March 2003 Quarterly Report, reiterated in the June 2003 Quarterly Report, and recently submitted in a continuation application on a draft SF 424, full funding of Phase 1 research through October 2004 will require:

1. Obligation of the remaining 10% ($204,282) Phase 1 research funds into the U.S. Treasury account.
2. Obligation of additional funds ($237,480) used for pre-Phase 1 (October 2001 through October 2002) research and project administration before execution of the DOE – BPXA contract in October 2002. The pre-phase 1 funds requested will enable extension of the Phase 1 contract through October 2004 and were requested in mid-September as contractually specified, no later than 60 days prior to the end of the current budget period (December 31, 2003), through a continuation application on a draft SF 424.
3. Obligation of additional funds ($45,000) to be used for Phase 1 reservoir modeling studies and to provide an industry-standard reservoir-economic model to help determine project progression into Phase 2.

An additional $400,000 was obligated to the project in October in response to the above cost requirements. Contracts and subcontracts will be updated in November 2003 to reflect these additional obligated funds and the anticipated Phase I project time-extension through end-October 2004.

2.2 Project Status Assessment and Forecast

Project technical accomplishments from July 2003 through end-September 2003 are presented by associated project task. The attached milestone forms (Appendix A) present project tasks 1 through 13 with task duration and completion timelines.

2.3 Project Research Collaborations

Progress towards completing project objectives significantly benefits from continued DOE support and/or funding of the following associated projects and proposals. Section 5.4 provides additional detail on collaborative research accomplishments during the reporting period.

1. **LBNL Reservoir Modeling studies:** This research includes code calibration to data collected during 2002 Mallik gas hydrate test program as well as working with the BPXA project to evaluate potential development scenarios. DOE has currently obligated project funds to continue LBNL reservoir modeling research. UAF seconded a graduate student to assist LBNL research in August 2003. BPXA and UAF met with LBNL on August 13-14, 2003. BPXA met with LBNL, Ryder-Scott, USGS, and DOE representatives on October 1, 2003 to determine how to best allocate project and DOE resources to gas hydrate reservoir modeling studies and to minimize potential duplication of gas hydrate reservoir modeling efforts between DOE-supported research projects.

2. **DE-FC26-01NT41248:** UAF/PNNL/BPXA studies to determine effectiveness of CO_2 as an enhanced recovery mechanism for gas dissociation from methane hydrate. Recent project status presentation updates and funding indicate a strong level of DOE support for this associated project during the reporting period. UAF has seconded a graduate student to PNNL to assist with this research. BPXA and UAF met with PNNL on August 11-12, 2003 to discuss project status, determine work progression, and discuss project synergies.

3. **UAF/Argonne National Lab project:** This associated project was recently approved for funding by the Arctic Energy and Technology Development Lab (AETDL) and forwarded to NETL for review. The project is designed to determine the efficacy of Ceramicrete cold temperature cement to future gas hydrate drilling and completion operations. Evaluating the stability and use of a cold temperature cement will greatly enhance the ability to maintain the low temperatures of the gas hydrate stability field during drilling and completion operations, helping to ensure safe and cost-effective operations.

4. **UAF/McMillan-McGee/PNNL proposal:** This proposal was recently highly ranked during presentations to AETDL, but not forwarded to NETL for funding at this time. The proposal also received strong letters of support from BPXA and Conoco-Phillips viscous oil development teams. The project would investigate in-situ electromagnetic (EM) heating as an enhanced recovery method for both viscous oil and gas hydrate production. In addition to depressurization of an adjacent free gas, this technology may thermally enhance gas dissociation from gas hydrate-bearing reservoirs and perhaps counteract any endothermic cooling reaction, thus providing greater flow assurance during gas production. A brief, independent assessment and first-principles numerical modeling of the EM methodology is being considered to determine whether or not to proceed with further proposals of this nature in support of potential Phase 2-3 operations procedures.

5. Progress toward completing the objectives of this project are aligned with a collaborative research agreement under evaluation between BPXA and Japan National Oil Corporation (JNOC). Execution of a BPXA – JNOC agreement will enable additional funding for technical studies and data acquisition. JNOC participation in Phase 1 research might also encourage JNOC participation in Phase 2 and/or 3 research should industry decide to progress into these operational phases of the research project.

6. India's Institute of Oil and Gas Production Technology (IOGPT) has also indicated a continued interest in participating with our Phase 1 research program. In September, DOE replied to India's unsolicited expression of research collaboration interest and indicated support for India to participate as an observer if the project should proceed into Phase 2 research.

7. An additional collaborative research project under the Department of Interior (DOI) would also provide significant benefits to this project. The BLM, USGS, and the State of Alaska recognize that gas hydrates are potentially a large untapped onshore energy resource on the North Slope region of Alaska. To develop a complete regional understanding of this potential energy resource, the BLM, USGS and State of Alaska (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. As interest in the resource potential of Alaska gas hydrates continue to grow, information generated from this agreement will help guide these agencies to promote responsible development of this potential arctic energy resource. The DOI project will work 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, both within and beyond current industry infrastructure.

2.4 **Project Performance Variance**

Contribution of shallow portions of PBU seismic data to the project under contractually specified confidentiality constraints is delayed, though discussion with industry partners and BPXA operations groups in PBU and MPU continues. BPXA is working both internally and with industry partners to emphasize the importance of this data to our gas hydrate reservoir and fluid characterization studies. While the 100% BPXA MPU seismic data is released (under confidentiality constraints) to the project, release of PBU data to the project is dependent upon industry partner approval.

PBU plans a new PBU seismic survey ("S-cubed") for early 2004. This seismic survey is specifically designed to enhance resolution of shallow oil resources and would also significantly enhance resolution of the shallow gas hydrate and associated free gas bearing shallow reservoirs within PBU and the Eileen trend area of interest. Before consideration of this survey for the latter purposes, the survey would require addition to the limited rights data defined within the BPXA – DOE contract in an amendment to that contract.

3.0 EXECUTIVE SUMMARY

This Quarterly report encompasses project work from July 1, 2003 through September 30, 2003. Sections 4 and 5 provide a detailed project activities report.

- Collaborated with LBNL and Ryder Scott Co. to develop an industry-standard reservoir model for gas hydrate and associated free gas reservoirs in study area
    - Studied EOSHYDR2 and dissociation prediction of gas hydrate in porous media
- Planned and executed Phase 1 time-cost extension through October 2004
- Finalized and documented project patent waiver
- Provided project summaries, informational briefings, and presentations to BPXA, Exxon-Mobil, Conoco-Phillips, BP in GOM, DOI, BLM, DOE, NETL, LBNL, PNNL
- Continued working with JNOC to define potential base and stretch well of opportunity operations and activities to enable Phase 1 project collaborative research
- Studied potential of electromagnetic (microwave and/or radiowave frequency) energy to enhance recovery of gas from gas hydrate by in-situ near-wellbore thermal method
- Completed additional log correlation studies and resolved stratigraphic discontinuities
- Characterized reservoirs, fluids, faults, and unconformities
    - Identified stratigraphic facies and completed gross sand maps in MPU area
    - Drafted petrophysical report to help predict shallow sand fluid saturations
- Created project base map illustrating log curves and fluid saturations
- Analyzed seismic waveforms to compare/contrast interpreted sediment facies changes versus interpreted gas hydrate occurrence and relate to changing wavelet character
- Began investigation of fault controls on reservoir distribution and gas hydrate presence
- Assessed well-to-seismic correlations and created/calibrated synthetic seismograms
- Assigned initial waveform classifications to gas hydrate bearing reservoir horizons
- Applied attribute analyses to detect facies and possible gas-gas hydrate fluid indicators
- Conducted Gas Hydrate Phase Equilibrium research and designed same for porous media
- Completed relative permeability experiment design, apparatus, and initial trials
    - Monitored gas and water injection/production, maintained low temperature, and achieved preliminary results for consolidated sand and mud cores (Hot Ice #1)
- Evaluated commercially available mud chiller systems for ANS drilling operations
- Considered experimental apparatus and core holder to investigate formation damage
- Encouraged collaborative research program with UAF and ANL to study efficacy of Ceramicrete as arctic conditions and chilled mud system drilling cement
- Studied various methods to recover, preserve, and transport gas hydrate-bearing core

4.0 EXPERIMENTAL

During the time period from July through end-September 2003 encompassed by this report, primary experimental activities consisted of experiment apparatus design, setup, and execution.

4.1 TASK 6.0, Reservoir and Fluids Characterization

The University of Arizona (UA) continued well and seismic data interpretation. Studies reveal shallow sand reservoir stratigraphic heterogeneity and structural compartmentalization. Section 5.6 provides additional details, results, and recommendations.

4.1.1 Subtask 6.1: Reservoir and Fluid Characterization and Visualization

Continued seismic and well log interpretation for reservoir and fluid characterization studies. Created a project base map illustrating log curves and fluid saturations.

4.1.2 Subtask 6.2: Seismic Attributes and Calibration

Analyzed seismic waveforms to compare and contrast interpreted sediment facies changes versus interpreted gas hydrate occurrence and related to changing seismic wavelet character. Began investigation of fault controls on reservoir distribution and gas hydrate presence. Assessed well-to-seismic correlations and created/calibrated synthetic seismograms. Assigned initial waveform classifications to gas hydrate bearing reservoir horizons and applied various seismic attribute analyses to detect facies and/or possible gas-gas hydrate fluid changes.

4.1.3 Subtask 6.3: Petrophysics and Artificial Neural Net

Definitive correlation between self-organizing-mapping neural net classifications of chosen seismic attributes and the distribution and quality of gas hydrate occurrence remains inconclusive. Suspect that the self-organizing-mapping neural net classifications relates primarily to sediment facies rather than to a direct seismic indicator of gas and/or gas hydrate. Plan to refine classifications with improved time-depth conversions.

4.2 TASK 7.0: Laboratory Studies for Drilling, Completion, and Production Support

The University of Alaska Fairbanks (UAF) designed experiments and apparatus for gas hydrate equilibrium and relative permeability studies. Sections 5.7 through 5.12 provide additional details, results, and recommendations.

4.2.1 Subtask 7.1: Characterize Gas Hydrate Equilibrium

Continued gas hydrate phase equilibrium research and designed experiment and apparatus for porous media testing.

4.2.2 Subtask 7.2: Measure Gas-Water Relative Permeabilities

Completed relative permeability experiment design, apparatus, and initial trials for measurement of gas-water relative permeability. Monitored gas and water injection and production, maintained low temperature, and achieved preliminary results for consolidated sand and mud cores from the Anadarko Hot Ice #1 well.

4.2.3 TASK 8.0: Evaluate Drilling Fluids – UAF

Evaluated commercially available mud chiller systems for potential use with ANS drilling operations. Considered experimental apparatus and core holder to investigate formation damage.

4.2.4 TASK 9.0: Design Cement Program – UAF

Encouraged collaborative research program with UAF and ANL to study efficacy of Ceramicrete as arctic conditions and chilled mud system drilling cement.

4.2.5 TASK 10.0: Study Coring Technology – UAF

Studied various methods to recover, preserve, and transport gas hydrate-bearing core.

5.0 RESULTS AND DISCUSSION

Project technical accomplishments from July 2003 through September 2003 are presented in chronological order by associated project task.

5.1 TASK 1.0: Research Management Plan – BP and Project Team

Task schedules are presented in the attached milestones forms (Appendix A). Expenditures by budget category and associated tasks are attached in Table 1.

- Coordinated, compiled, and fulfilled project reporting requirements
    - Reformatted March 2003 Quarterly report for resubmission in contractually defined format
- Reviewed, processed, and ensured budget consistency of subcontractor invoices
- Prepared subcontract and scope-of-work for additional gas hydrate reservoir model work
    - Subcontracted to Ryder Scott Company to help provide industry-standard gas hydrate reservoir model
- Finalized Patent Waiver documentation with DOE
- Submitted draft SF424 to NETL for project time-cost extension for 2-year research period through end-October 2004
    - DOE obligated $400,000 of cost extension in October 2003
    - Expect to finalize contracts and subcontracts for phase 1 time extension through end-October 2004 within November 2003
- Provided project financial status updates and working to complete reporting requirements
- Recommended edits to SAIC gas hydrate projects summary document for DOE report
    - Added related project research collaborations
    - Clarified budget to ensure consistent with BP tracking

5.2 TASK 2.0: Provide Technical Data and Expertise – BP, USGS

- Met with PBU data owners to present project summary and determine potential and timing for release of PBU seismic data to gas hydrate project
    - Co-owner interest in project is sincere
    - Co-owner support and timing to release PBU data to project is less certain
- Released 38 additional wells with multiple well logs to project within area of interest
- Working to release additional relevant drilling and well file data to project

5.3 TASK 3.0: Wells of Opportunity, Data Acquisition – BP

- Provided input to logging plans for potential wells-of-opportunity
- Evaluated MPU K-pad opportunity, but sidetracking existing well too deep
- Continued working with JNOC to define potential base and stretch well of opportunity operations and activities to enable Phase 1 project collaborative research

TABLE 1: Expenditures, DE-FC-26-01NT41332, September 2003 Quarterly Report

BUDGET PERIOD 1 (2 year) COSTS SUMMARY

BP AFE #	Cost Category	% Obligated	NET COSTS	Budget Period 1	GROSS COSTS	SPENT COSTS	BALANCE FUNDS	REMAINING
GS2420H01	U. Arizona, Labor	90.168%	$779,125	$864,077	$779,125	$428,941	$350,184	45%
GS2420H02	U. Arizona, Travel	90.168%	$43,473	$48,213	$43,473	$7,515	$35,958	83%
GS2420H03	U. Arizona, Third Party	90.168%	$55,735	$61,812	$55,735	$39,047	$16,688	30%
GS2420H04	U. Arizona, Operations	90.168%	$155,311	$172,245	$155,311	$39,305	$116,006	75%
GS2420H05	U. AK Fairbanks, Labor	90.168%	$414,007	$459,148	$414,007	$60,106	$353,901	85%
GS2420H06	U. AK Fairbanks, Travel	90.168%	$26,528	$29,420	$26,528	$0	$26,528	100%
GS2420H07	U. AK Fairbanks, Third Party	90.168%	$39,791	$44,130	$39,791	$39,001	$791	2%
GS2420H08	U. AK Fairbanks, Operations	90.168%	$89,029	$98,736	$89,029	$11,631	$77,398	87%
GS2420H09	BPXA, Third Party Labor*	90.168%	$236,284	$262,047	$236,284	$175,513	$60,771	26%
GS2420H10	BPXA, Travel	90.168%	$25,247	$28,000	$25,247	$10,654	$14,593	58%
GS2420H11	BPXA, Operations	90.168%	$9,017	$10,000	$9,017	$2,915	$6,102	68%
	*TOTAL**	90.168%	$1,873,546	$2,077,828	$1,873,546	**$814,627**	$1,058,919	57%

* Only includes DOE funds

BP AFE #	Cost Category	Project Tasks**
GS2420H01	U. Arizona, Labor	Task 6.0, 6.1, 6.2, 6.3
GS2420H02	U. Arizona, Travel	Task 6.0, 6.1, 6.2, 6.3
GS2420H03	U. Arizona, Third Party	Task 6.0, 6.1, 6.2, 6.3
GS2420H04	U. Arizona, Operations	Task 6.0, 6.1, 6.2, 6.3
GS2420H05	U. AK Fairbanks, Labor	Tasks 7, 8, 9, 10, 11, 13
GS2420H06	U. AK Fairbanks, Travel	Tasks 7, 8, 9, 10, 11, 13
GS2420H07	U. AK Fairbanks, Third Party	Tasks 7, 8, 9, 10, 11, 13
GS2420H08	U. AK Fairbanks, Operations	Tasks 7, 8, 9, 10, 11, 13
GS2420H09	BPXA, Third Party Labor	Tasks 1, 2, 3, 4, 11, 12, 13
GS2420H10	BPXA, Travel	Tasks 1, 2, 3, 4, 11, 12, 13
GS2420H11	BPXA, Operations	Tasks 1, 2, 3, 4, 11, 12, 13

** Project Task 5.0 performed by USGS under separate funding

5.4 TASK 4.0: Research Collaboration Link – BP, USGS, Project team

- Coordinated reservoir modeling plans with DOE, LBNL, UAF, and Ryder Scott Co.
    - o Helped arrange UAF graduate student, Steven Howe, brief secondment to LBNL
- Subcontracted to Ryder Scott Company to provide industry-standard reservoir modeling
    - o Plan to minimize possible scope-of-work duplication with other research programs
- Studied potential of electromagnetic (microwave and/or radiowave frequency) energy to enhance recovery of gas from gas hydrate by in-situ near-wellbore thermal method
    - o May perform first-principles thermodynamics modeling study to determine feasibility of downhole electromagnetic thermal recovery enhancement
    - o Circulated ideas through BP research and viscous oil communities for synergies
- Continued to work toward BPXA – JNOC collaborative research agreement
    - o Assessed relevant confidentiality and intellectual property provisions
    - o Restructured initial agreement draft to Memorandum of Understanding format
    - o Prepared draft 2003-2004 Implementation Agreement
- Established dialog with DOE regarding India Ministry of Petroleum request to DOE for participation in project as observer
- Provided input to agenda and presentations for AAPG Hedberg Conference on gas hydrates planned for September 2004
    - o Conference will provide a major opportunity to present Phase 1 study results
    - o Anticipate 3-5 conference presentations and 5-10 attendees from this project
- Met with Pacific Northwest National Lab staff at PNNL facility with UAF staff
    - o Toured gas hydrate research program lab facilities
    - o Discussed gas hydrate research synergies and PNNL-UAF-BP research program: CO2 injection as potential enhanced gas recovery method from methane hydrates
    - o Discussed related PNNL research projects and synergies
- Met with Lawrence Berkeley National Lab staff at LBNL facility with UAF and Ryder-Scott Company staff
- Actions from LBNL meeting include:
    1. LBNL: provide Beta-test reservoir model to team for development by Jan. 2004
        a. LBNL: Include model code calibration to 2002 Mallik testing
        b. BPXA team: provide user input before and during Beta-testing
        c. BPXA team: provide industry-standard assistance to LBNL for UA-UAF-developed reservoir/fluid scale-up and development plan optimization
    2. LBNL-BPXA-DOE: collaboratively develop work plan and prioritize sensitivities
    3. DOE-BPXA: collaborate to minimize distractions to LBNL primary scope-of-work
- Presented project interim results and summary at DOE conference in Denver
    - o Helped develop DOE gas hydrate program and GOM JIP synergies
    - o Organized reservoir modeling meeting to discuss industry-standard reservoir model development and to reduce possibility of scope-of-work redundancies
    - o Led to invitation to present to National Research Council in Houston (October)
- Submitted AAPG Abstract for 2004 National Conference, entitled: "Reservoir-Fluid Characterization and Reservoir Modeling of Potential Gas Hydrate Resources, Alaska North Slope"
    - o Integrated UA reservoir characterization abstract into a team abstract for oral presentation at the 2004 Annual AAPG Convention in Dallas

- Discussed gas hydrate research and viscous oil synergies with BLM and Conoco-Phillips
    - BLM approach to gas hydrate research is 2-fold:
        1. Participate in technology development for potential production of unconventional resources such as gas from gas hydrate
        2. Prepare earlier for potential regulatory aspects for unconventional resource development to streamline permitting and address environmental concerns
- Presented project summary to NETL Director, Rita Bajura during September Alaska visit

5.5 TASK 5.0: Logging and Seismic Technology Advances – USGS, BP

- Provided input to potential wireline and LWD logging data acquisition plans
- Investigated seismic attribute analyses for direct gas-gas hydrate indicators

5.6 TASK 6.0: Reservoir and Fluids Characterization – UA

5.6.1 Subtask 6.1: Reservoir and Fluid Characterization and Visualization – UA

5.6.1.1 Products and Preliminary Findings

- Completed two additional field-wide log correlation studies
    - Resolved stratigraphic discontinuity issues and correlation loop-tie problems
    - Substantiated more difficult correlations in lower, more discontinuous units
    - Enabled easier correlations in upper parasequences by establishing the presence of several transgressive marine shale units
    - Released higher resolution version of schematic chronostratigraphic cross-section (Figure 1), first included in June 2003 Quarterly Report
    - Trained student researchers in litho- and chrono-stratigraphic correlation methods
- Identified stratigraphic facies for the MPU study area
    - Completed draft Gross Sand maps for interpreted stratigraphic horizons
    - Maps used in reservoir characterization, syndepositional faulting analyses, intraformational unconformity evaluation, and other (Figures 2-6)
- Normalized GR logs to correct for anomalous tool response
    - Only ~58/90 wells had GR logs of sufficient quality for log normalization
    - GR normalization is required for accurate net sand and net pay calculations
- Completed preliminary report on investigation of new log-based fluid saturation algorithm
    - Used sonic, density and resistivity well logs to develop prediction algorithm
    - Predicted pore fluid saturations for gas hydrate, ice, free gas, and water (Figure 7)
        - Study includes 10 wells with required seismic velocity and resistivity data
        - Wells studied include: Eugnu-01, KRU Ugnu-01, WSak-17, WSak-25, MPE-26, MPA-01, MPD-01, MPB-02, NWEileen-02, and MPS-15
    - Defined base of ice stability zone in MPU area
    - Prediction model may enable identification of the base of the ice stability zone
    - Model may also differentiate thin-bedded gas hydrates from taliks (ice-free zones)
    - Added base of ice stability fluid horizon pick in the MPU area to UA database
- Added gas hydrate occurrences and base permafrost as inferred by Collett to UA database
- Noted and corrected discrepancies in Collett's gas hydrate zones in UA database
- Posted all available wells with velocity data (e.g. VSP, check shot surveys, etc.) and synthetic seismograms to a "log curve" base map (Figure 8)

  - Map shows the presence/absence/depth for log curve types of each well
- Received additional open-hole and cased-hole well data in the eastern MPU area from BP
  - Added Log curve data and well header data required for well posting/mapping
  - Plan to analyze well data to confirm preliminary interpretation of rapid facies and reservoir fluid changes between closely spaced wells
- Helped GEOS with well-to-seismic correlations for wells with sonic and density logs
- Produced net sand maps on PETRA for several gas hydrate-prone intervals in MPU
- Completed preliminary sand-shale ratio maps for some reservoir sand intervals
- Completed research regarding reservoir calculations and log analyses of coal versus sand

5.6.1.2 Miscellaneous Project Activities

- Convened Gas Hydrate Research Group Meetings and work sessions
  - Discussed project status and data correlation issues
  - Developed strategy, planning, and feedback for Fall research activities
  - Discussed progress with seismic work and well log correlation work
  - Discussed group data needs and research integration for volumetric analyses
- Contributed seismic map example for BP project presentation to Denver DOE conference
- Continued data compilation and quality control
- Continued familiarization with UNIX Landmark and Windows Petra/PetraSeis software
- Scheduled software and hardware maintenance/upgrades and database backups
- Provided project management and related administration activities
- Wrote abstract and created poster on student gas hydrate research activities
  - Presented to 2003 AAPG Student Expo conference in Houston (October 2003)
- Collaborated between UA geophysics (GEOS) and geological (MGE) groups
  - Completed Bo Zhao (MGE) MS thesis in August 2003
  - Modeled seismic characterization results and interpretations
  - Investigated use of self-organizing map (SOM) neural network classifications of seismic attributes to characterize gas hydrate-bearing sediment facies within MPU
- Prepared GEOS poster and abstract for December 2003 AGU San Francisco conference: “Beyond Hydrate Ridge: Studies of Natural Gas Hydrate from Around the Globe”
- Assessed, discussed, and developed outline, introduction, and geologic background for Casey Hagbo’s MS thesis (in press)

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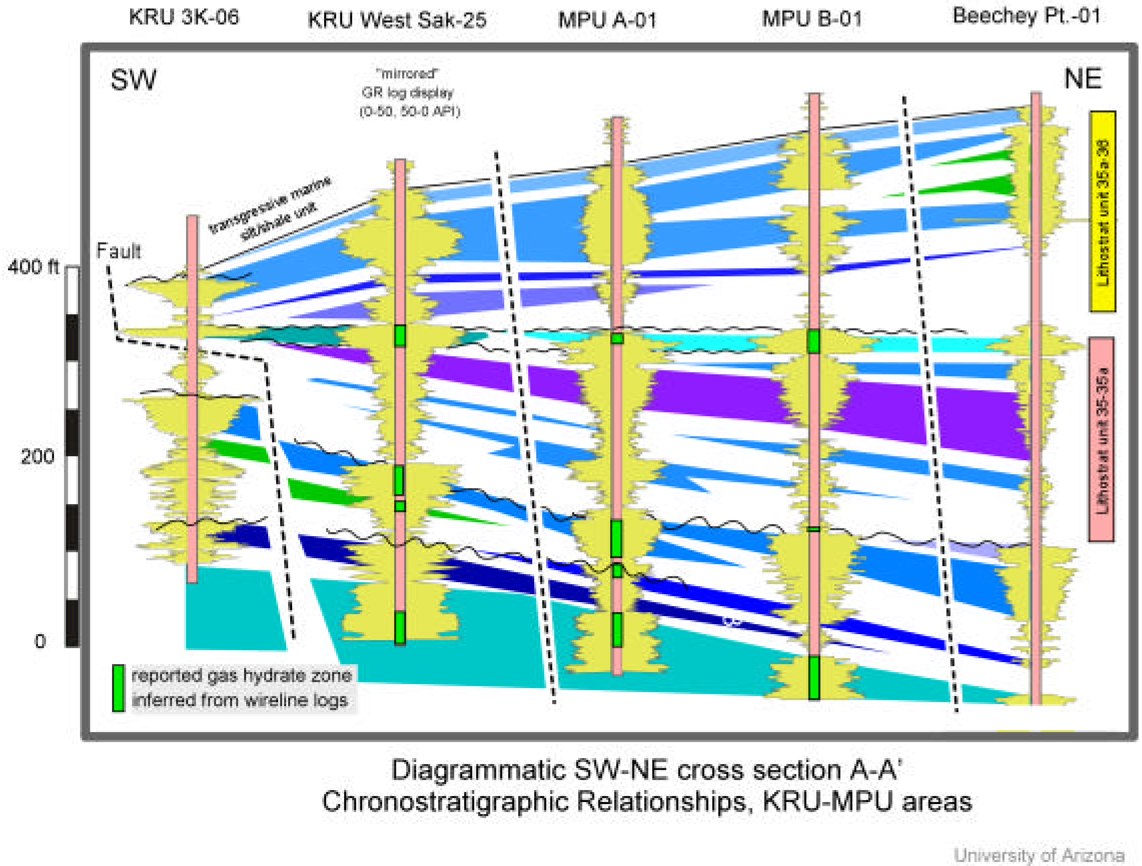

Figure 1: Schematic Regional Cross-section illustrating Chronostratigraphic Correlations at enhanced resolution (initially published at lower resolution as Figure 4 in June 2003 Quarterly Report).

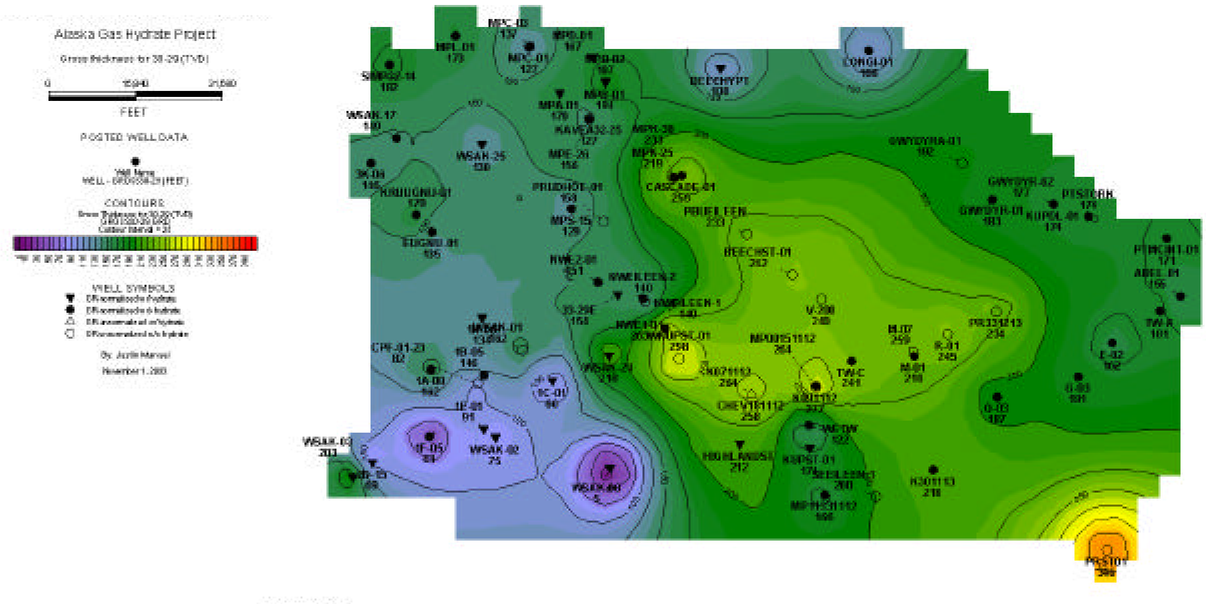

Figure 2: Draft gross interval isopach for UA Sagavanirktok horizons 30-29

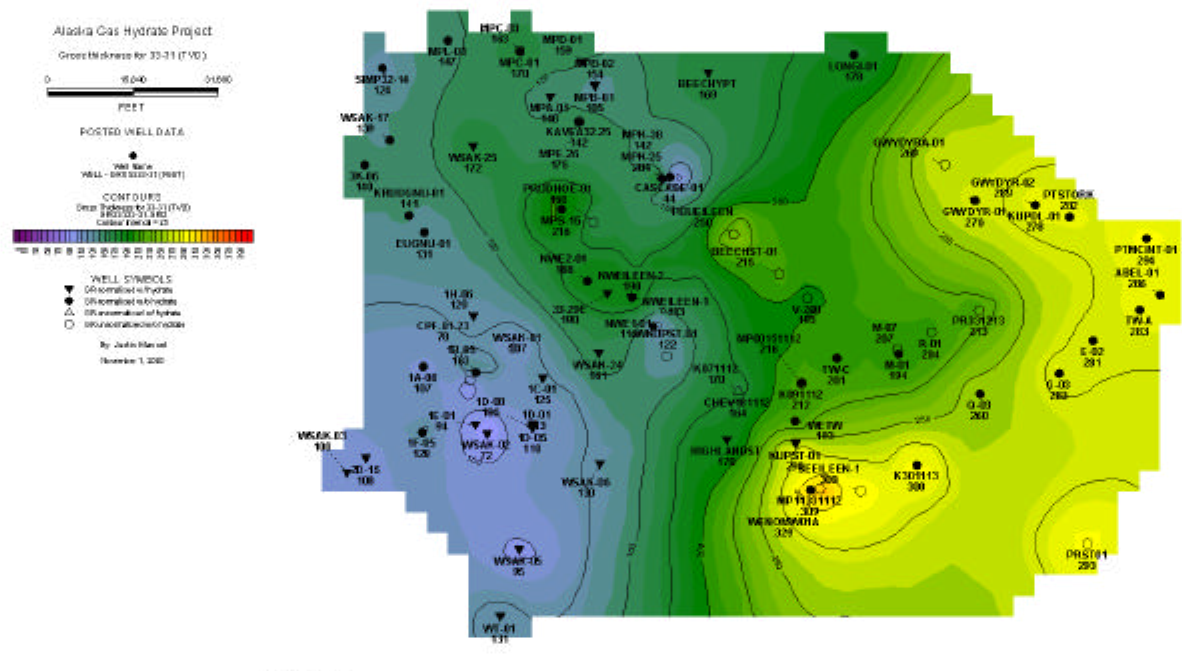

Figure 3: Draft gross interval isopach for UA Sagavanirktok horizons 33-31

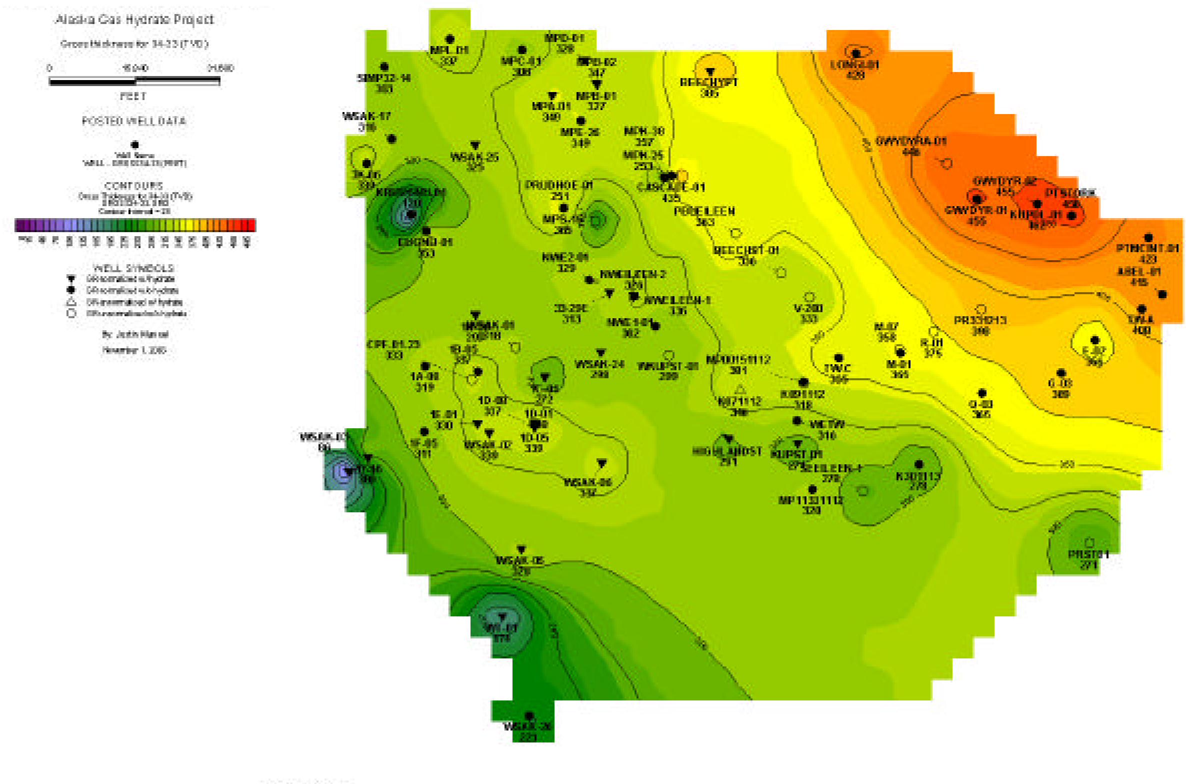

Figure 4: Draft gross interval isopach for UA Sagavanirktok horizons 34-33

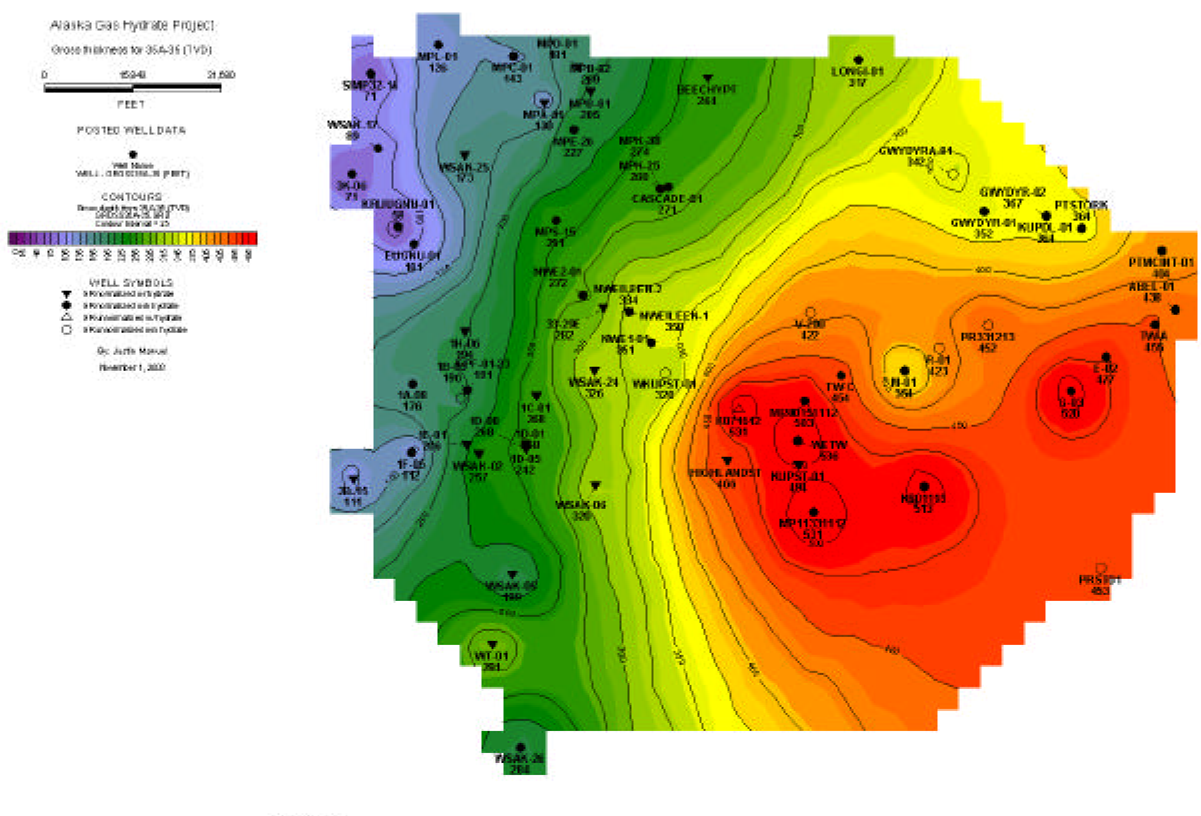

Figure 5: Draft gross interval isopach for UA Sagavanirktok horizons 35a-35

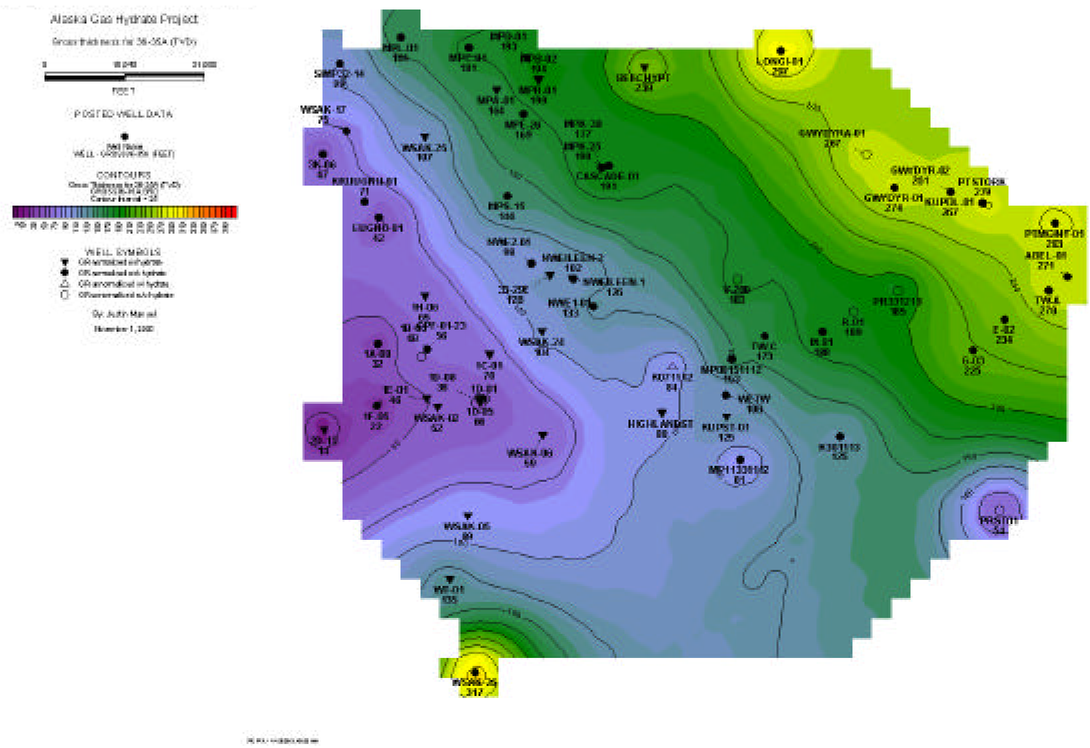

Figure 6: Draft gross interval isopach for UA Sagavanirktok horizons 36-35a

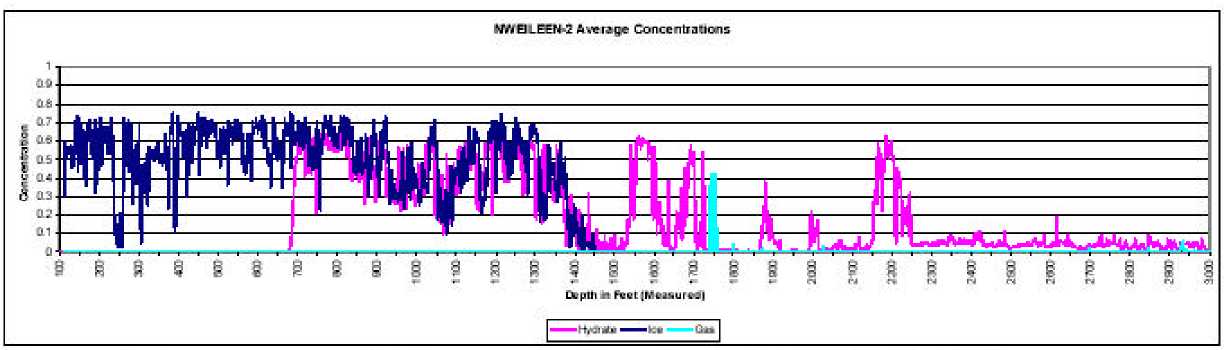

Figure 7: Average ice, gas hydrate, and free gas pore fluid concentrations for well NWEileen-02 (from preliminary draft UA report by C. Glass)

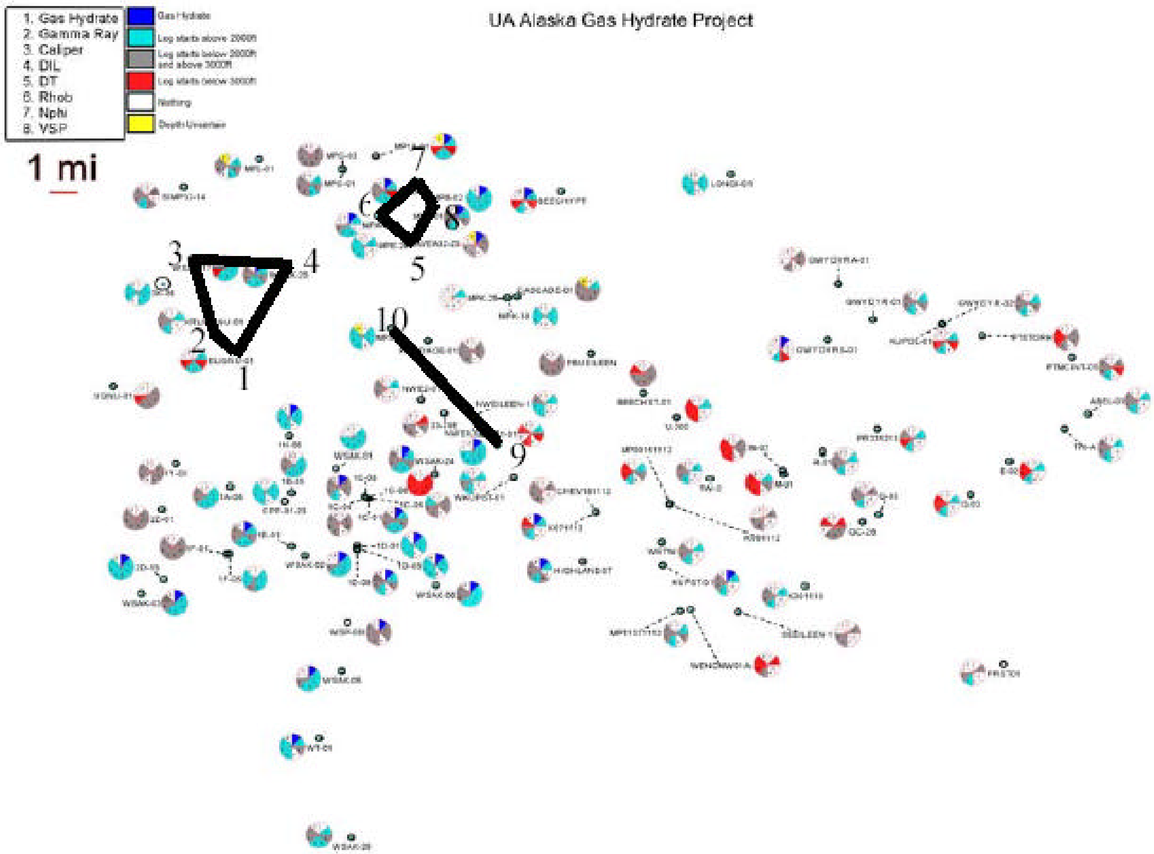

Figure 8: Study area base map illustrating location of wells with estimated pore fluid saturations

5.6.1.3 Work in Progress

- Constructing gross interval and net sand isopach maps associated with inferred and interpreted gas hydrate-bearing zones (Figures 2-6)
    - Mapping and correlation editing are iterative process
    - Working preliminary isopach maps for Sagavanirktok horizons (Figures 2 – 6)
- Beginning seismic wavelet/waveform analyses
    - Study will attempt to differentiate affects of interpreted sediment facies changes versus interpreted gas hydrate occurrence and relate to changing wavelet character
    - Figure 8 shows a draft waveform classification of USGS Sagavanirktok Unit_C horizon, equivalent to the UA stratigraphic and seismic horizon “corr_mkr_34”

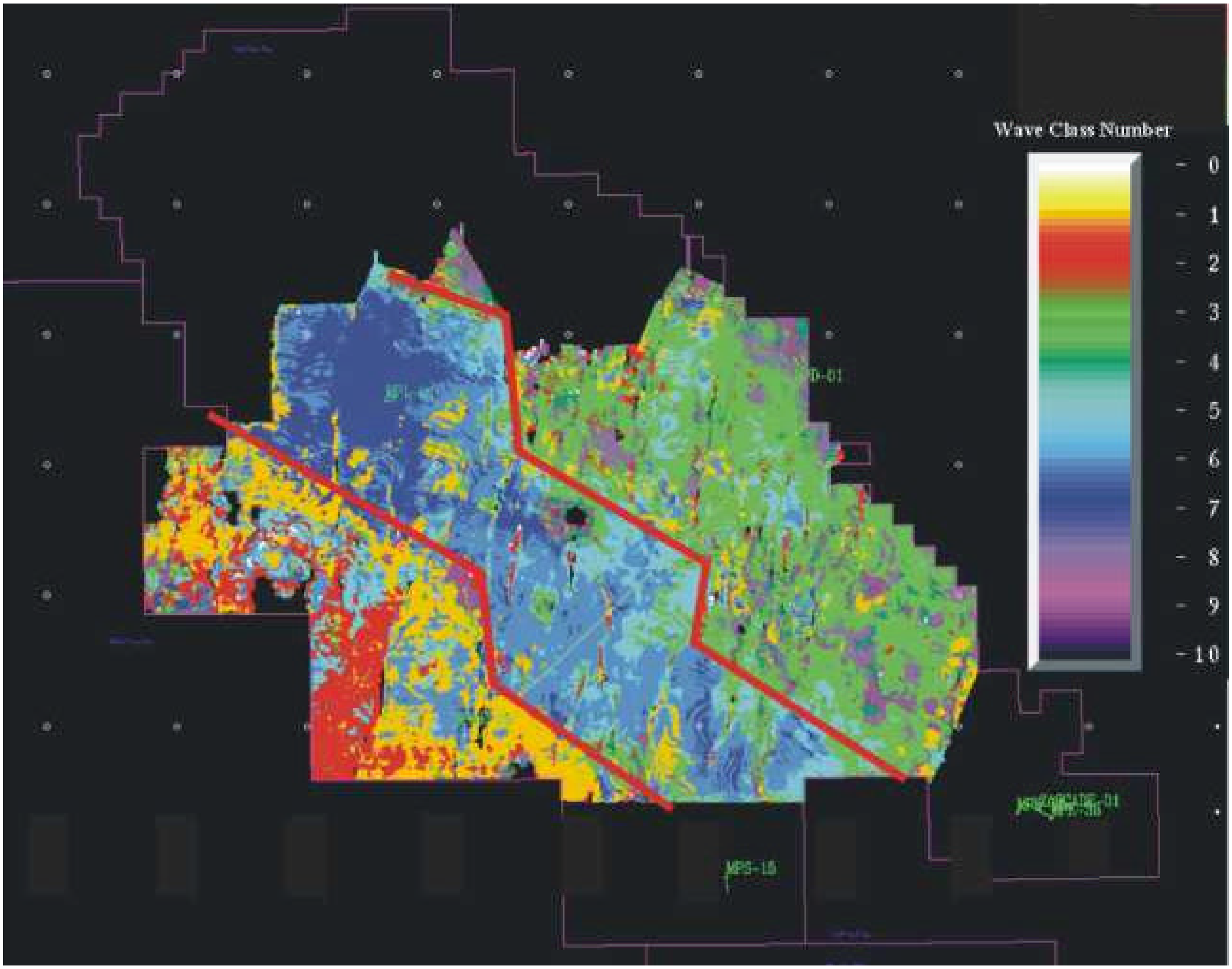

Figure 9: Milne Point 3D seismic survey draft waveform classification of USGS Sagavanirktok Unit_C, equivalent to UA stratigraphic and seismic horizon “corr_mkr_34”

- Investigating fault controls on sand quality, distribution and associated gas hydrate occurrence within the MPU
    - Figure 9 shows a fault contour map with depth in feet. The time-to-depth conversion was completed using the supplied checkshots and time depth tables from the best synthetics to date

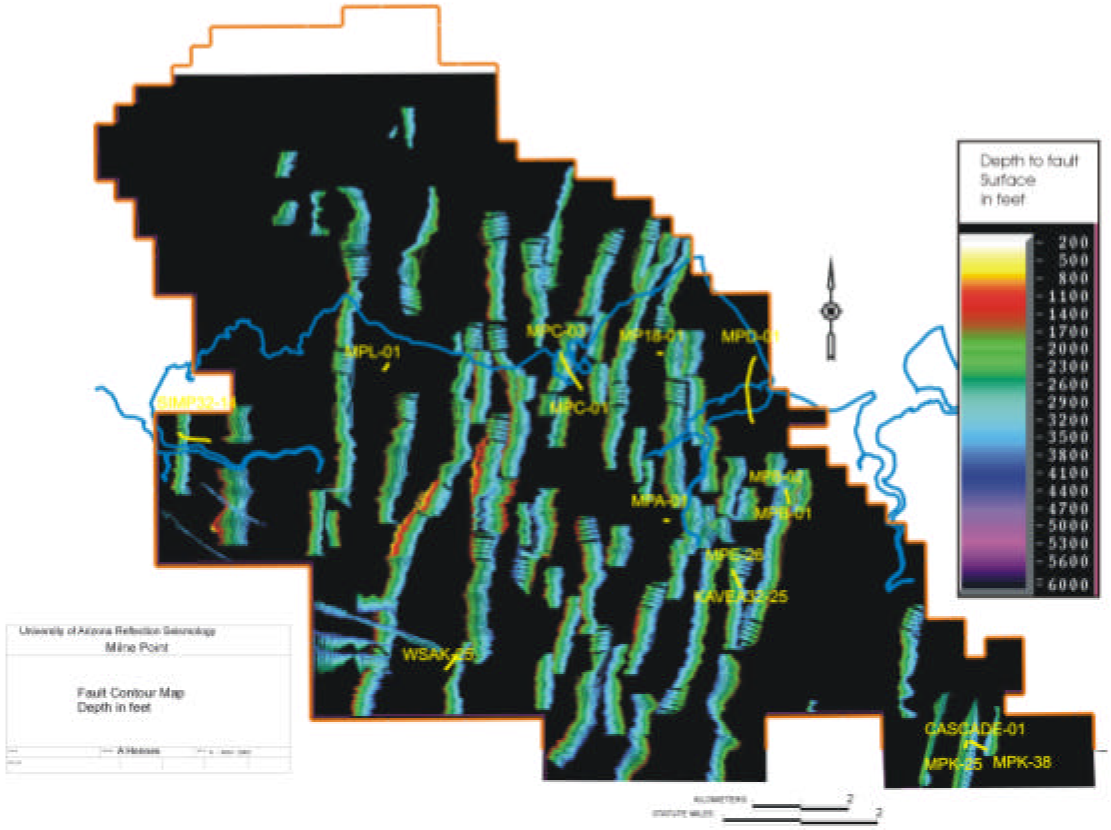

Figure 10: Milne Point 3D seismic survey fault contour depth map

- Classifying well log patterns and interpretation of sand body facies types and depositional environments in the MPU area.
  - Plan to integrate facies maps with net sand/pay maps to calculate volumetrics and help estimate recovery factors.
  - Resulting maps will also contribute to a preliminary log-based paleo-depositional reconstruction of the Sagavanirktok formation
  - Plan to analyze this data and compare/contrast to gas hydrate occurrences as interpreted and inferred by Collett and the UA team
- Identifying distribution of coal-bearing units within the Sagavanirktok formation
- Continuing training on Landmark and GeoPlus workstations
- Constructing cross-sections, generating maps, computing data, characterizing reservoirs
- Completing security and nightly backup of database, project files and software system files

5.6.1.4 Continuing needs and data

- Purchase of third-party software to convert Landmark CGM output files into common graphic image formats (e.g. TIFF, PICT, JPEG) is anticipated by end-October
- Obtain well logs in the Tarn producing area to the southwest of KRU

- Obtain mudlog, drilling log, and well file information related to significant Sagavanirktok borehole washouts, gas shows, and penetration rate anomalies
- Obtain deeper seismic data to link with deep well log information to improve interpretation of shallower and poorer quality seismic data
- Assess availability and obtain a deeper fault map (e.g. LCU or Pebble Shale level) to calibrate with the shallower seismic fault data in the MPU-Eileen area
- Receive on-site assistance from a BP or Landmark technical representative to assist creation of a comprehensive base map of all geological and pertinent cartographic data
    - Obtain and incorporate cartographic data showing distribution of most thaw lakes, river and stream courses and shoreline configuration
    - During the pre- and post proposal stage, BP indicated probable support for occasional onsite visit by a Landmark representative currently assigned to BP
        - Local Landmark representative will be selected to provide this support
        - Investigate use of current representative assigned to USGS in Denver

5.6.2 **Subtask 6.2: Seismic Attributes and Calibration – UA**

5.6.2.1 Products

- Assessed well-to-seismic correlations for wells with adequate velocity and density logs
- Compared UA synthetics/well ties with synthetics and approximate well ties from USGS
- Edited selected velocity and density logs to improve synthetic seismograms
- Created synthetics using different wavelet characteristics to better match USGS synthetics
- Calibrated synthetics using marker horizon mkr 36 (approximate equivalent to SV5)
- Imported MGE well picks into SeisWorks for seismic mapping
- Mapped gas hydrate bearing C & E Units (from well picks defined by T. Collett)
- Created more accurate depth to time conversions and synthetics for MP18-01, Kavea32-25, MPB-01, MPA-01, and WSak25
- Mapped seismic-equivalent horizons as defined by MGE correlation studies for stratigraphic horizons (mkr 30, mkr 26, mkr33, mkr 36, mkr 39)
- Assigned preliminary waveform classifications to gas hydrate bearing horizons (Figure 8)
- Tested application of direct seismic facies detection and possible gas hydrate indicators
- Created amplitude balanced data volumes to assess normalized horizon-amplitude
- Created amplitude extraction maps of several seismic attributes for gas hydrate bearing units and for several stratigraphic horizons (Figure 10)
    - Extracted amplitude maps from predictive decon volume with amplitude balancing
- Created a preliminary merged Milne Point and Northwest Eileen Project and mapped the SV5/mkr 36 across the merged project
- Created a velocity model for the Milne Point 3D Seismic Survey using time-depth tables from check-shots and synthetics
- Converted 2-ms seismic data, faults, and horizons to depth
- Exported depth-converted faults to assist MGE well correlation and picks in StratWorks

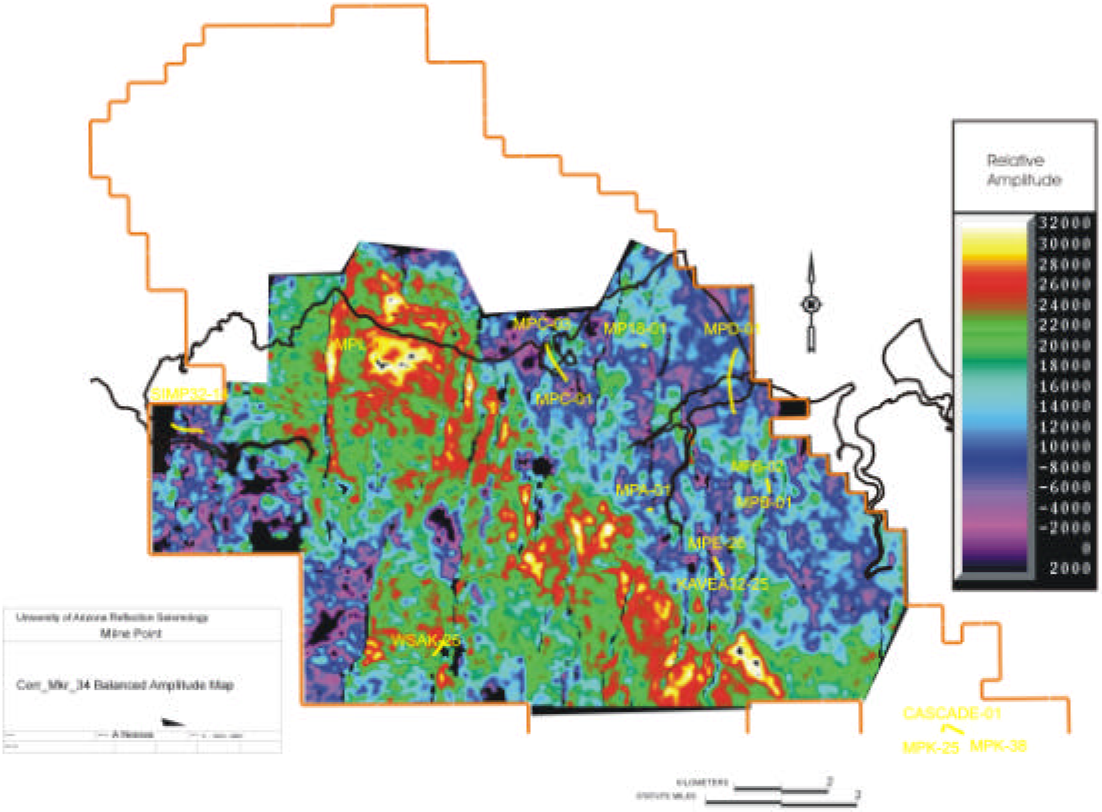

Figure 11: Draft amplitude extraction map example for seismic horizon that correlates to UA stratigraphic horizon "corr_mkr_34". Extracted amplitude map from predictive decon volume with amplitude balancing.

5.6.2.2 Work in Progress

- Refining seismic horizon maps in collaboration with MGE horizon correlations
- Tying amplitude and waveform classification maps to well correlation interpretations
- Ongoing mapping based on additional well log picks and refined well correlations
- Two Master's Theses in progress (Casey Hagbo and Andrew Hennes)
  - Casey Hagbo expected MS Thesis completion by December 2003
- Defining/refining seismic characteristics to interpret gas hydrate occurrence near wells
- Refining velocity model and depth conversion for use in more detailed horizon thickness and fault heave/throw studies

5.6.2.3 Continuing Needs

- Obtain access to more accurate shallow velocity model for MPU region (used by BP)
  - 3-D stacking velocity model for shallow section (above 950 ms) for more accurate depth conversions.
  - Additional near-, intermediate- and far-offset stack volumes for AVO analyses for fluid characterization and gas hydrate identification.

- Obtain well log ties to seismic data based on deeper correlations with better data quality
  - Enable sufficient signal length for more accurate correlations
- Obtain detailed processing history for assembled data sets
- Incorporate GIS geological data for region and other pertinent geological and cartographic data (e.g. more detail on deep thaw lake distributions)

5.6.3 Subtask 6.3: Petrophysics and Artificial Neural Net – UA

5.6.3.1 Products

- Reviewed , completed, and published Bo Zhao's MS Thesis entitled "C*lassifying Seismic Attributes in the Milne Point Unit, North Slope of Alaska"*
  - Definitive correlation between self-organizing-mapping neural net classifications of chosen seismic attributes and gas hydrate distribution remains inconclusive
  - Suspect the self-organizing-mapping neural net classifications relate primarily to sediment facies rather than to a direct seismic fluid indicator
  - Plan to refine classifications with additional and improved time-depth conversions

5.6.3.2 Work in Progress

- Analyzing well log information and setting up calculations in PETRA for water and gas saturation, volume shale, and porosity
- Applying new self-organizing-mapping neural net classifications of well log curves
- Studying fluid saturation algorithms; completed preliminary internal report (under review)

5.7 TASK 7.0: Lab Studies for Drilling, Completion, and Production Support – UAF University of Alaska Fairbanks

Name and address	**Shirish Patil (PI)**	**Abhijit Dandekar (Co-PI)**
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Approximate Program Start Date: **7/1/02** (Contracted November 2002)
Phase I Program Anticipated Completion Date: **10/31/04**

UAF Participating Scientists: David Ogbe, Godwin Chukwu and Santanu Khataniar
UAF Graduate Students: Jason Westervelt, Stephen Howe, Namit Jaiswal, and Prasad Kerkar
UAF Undergraduate Student Assistant: Phillip Tsunemori

5.7.1 **Subtask 7.1: Characterize Gas Hydrate Equilibrium**

5.7.1.1 Work in Progress

- Conducted Gas Hydrate Phase Equilibrium experiments
- Installed visual cell inside the Tenny air bath apparatus that would allow measurements to be conducted in a porous media (Figure 11)

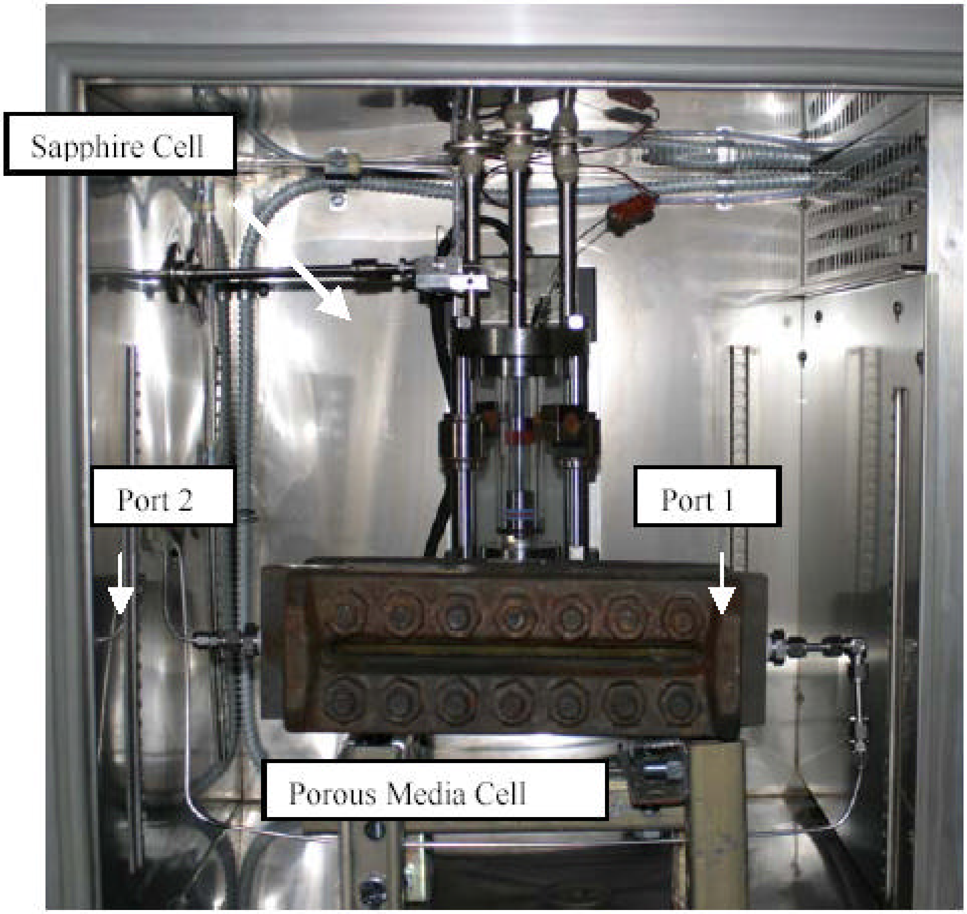


Figure 12: Temperature controlled air bath with sapphire cell and porous media cell

The porous media currently used is unconsolidated quartz sand that is incorporated into the cell by dissembling the cell. Once the cell is reassembled the brine of known concentration is manually injected through port 1. After the cell is saturated with brine it is placed into the air bath. Port 2 is closed and methane is then injected through port 1. The way the cell is set up, the pressure and temperature readings in the sapphire cell correspond to the porous media cell. Since there is no temperature reading device inside the porous media cell the temperature change during an experiment is slow in order to reach an equilibrium temperature. The change in temperature is 0.1°F per ten minutes.

Several experiments were conducted to determine the proper technique that would give accurate results of the gas hydrate formation/dissociation temperatures and corresponding pressures. Analyzing the pump readings and time, gas hydrate equilibrium data are plotted. The results for experiments conducted with and without porous media are presented in Figures 12 and 13.

5.7.1.2 Future Work

- Continue conducting experiments in a porous media using a 2% brine concentration
    - Conduct multiple tests to ensure data reproducibility
- Conduct experiments in the quartz porous media using different brine concentrations
- Perform experiments on sample reservoir sand from Anadarko Hot Ice #1 well core
- Analyze the results to determine the gas hydrate stability zones
    - Compare this data with results of University of Arizona and USGS analyses of the seismic data/fluid characterization to determine the gas hydrate stability zone

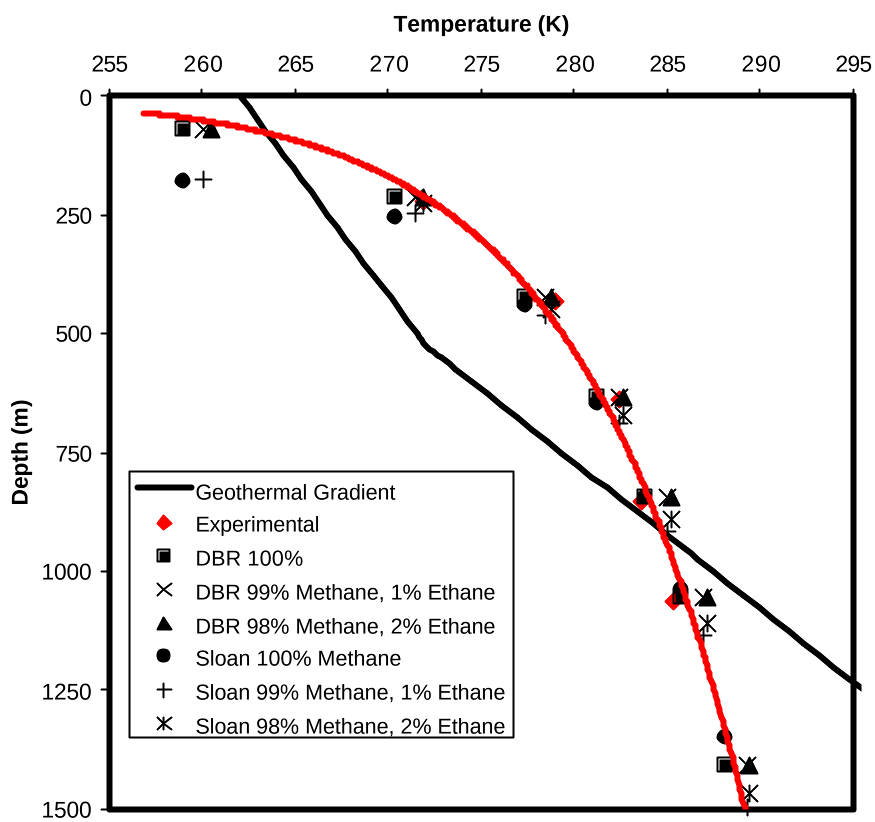


Figure 13: Methane Hydrate Stability Data for 2% Brine without Porous Media

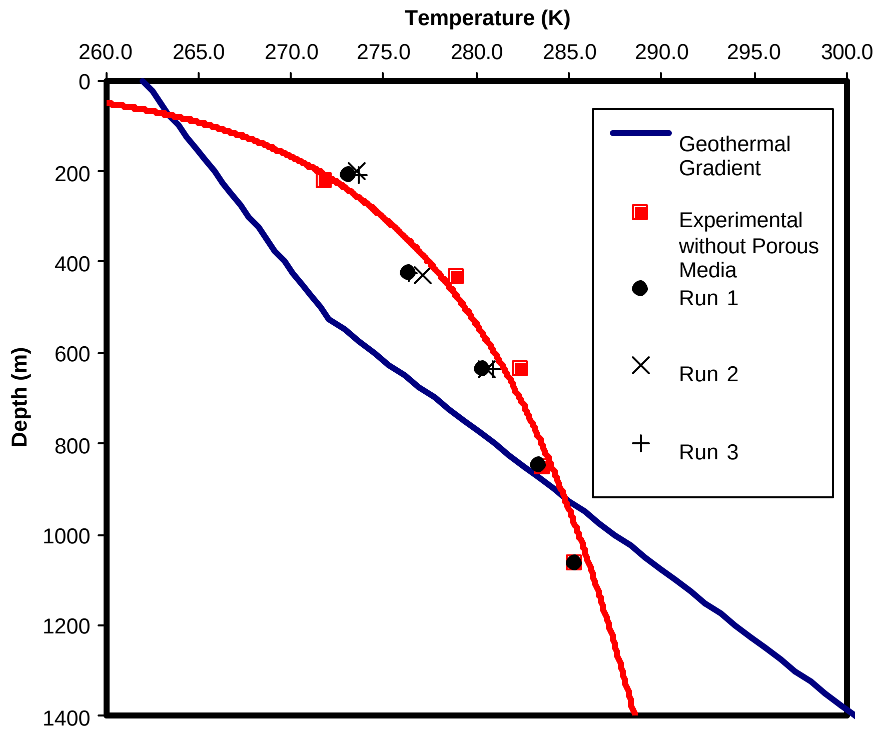


Figure 14: Methane Hydrate Stability Data for 2% Brine in Porous Media

5.7.2 Subtask 7.2: Measure Gas-Water Relative Permeabilities

5.7.2.1 Subtask 7.2 Objective

The objective of the project is to measure the relative permeability function relationships by conducting two phase relative permeability experiments and to assess gas productivity from gas hydrate bearing porous media. The current research plays important role in the simulation studies for future gas hydrate zone drilling, completion, and production. The simulation study is one of the important tasks to be carried out in ongoing research.

5.7.2.2 Experimental Setup

The experimental set-up for measurement of gas-water relative permeability was completed last quarter (June 2003 Quarterly Report). Additional components of the apparatus, such as high-precision weighing balance (for logging water production data), and data collection modules for system pressure and gas production were ordered. A schematic of the modified experimental set-up for measurement of relative permeability is shown in Figure 14. Figure 15 illustrates the actual experimental apparatus setup at the UAF laboratory. Preliminary apparatus tests were described in the June 2003 Quarterly Report.

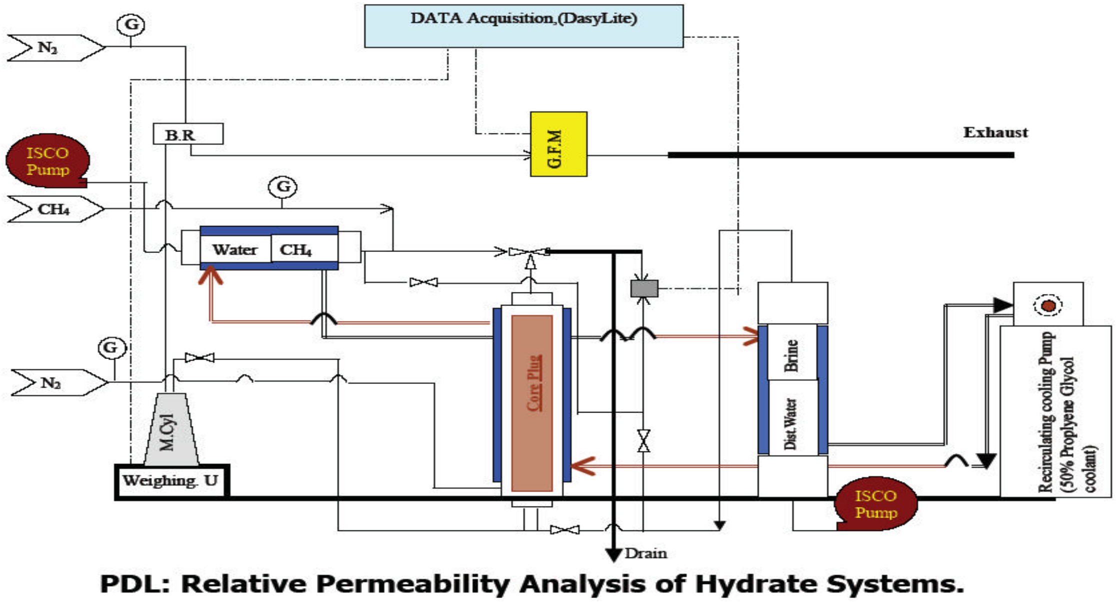


Figure 15: Modified experimental apparatus for gas-water relative permeability measurement

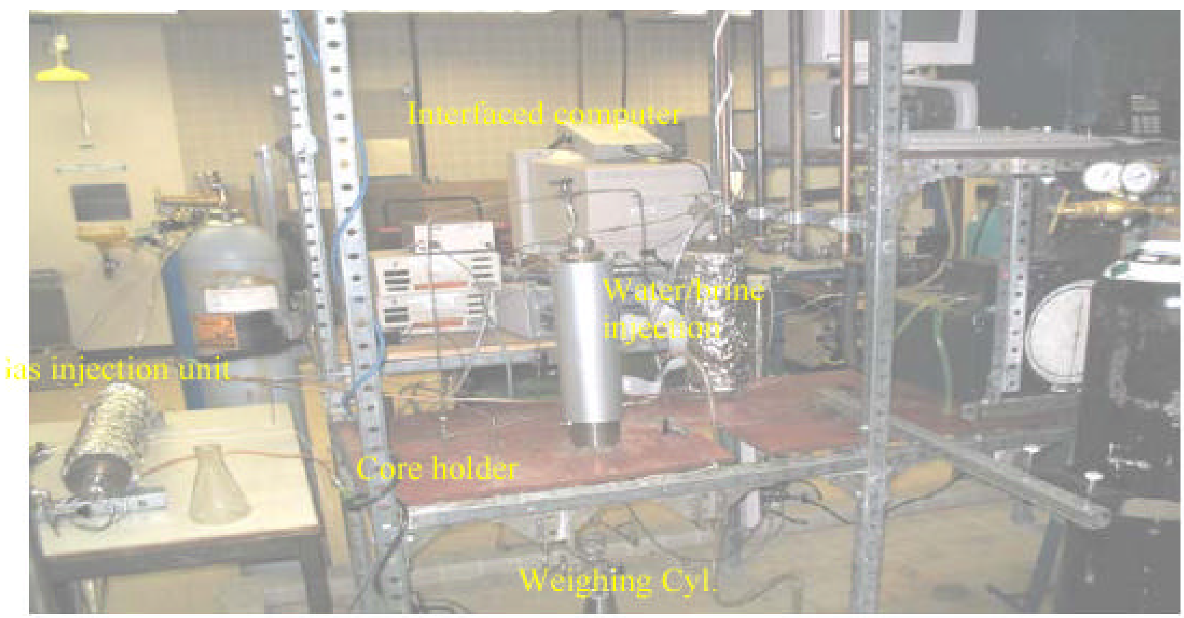


Figure 16: Relative permeability experimental apparatus set-up at UAF laboratory (9/22/2003)

5.7.2.3 Methodology

Due to the friable and the heterogeneous nature of permafrost and shallow core samples, laboratory techniques for measuring relative permeability are difficult. Laboratory analyses of gas hydrate-bearing core specimens are further complicated by the difficulty in accurately measuring the pore volume of gas hydrate samples. The present work will perform the necessary theoretical and experimental research required to adequately characterize the two-phase fluid flow in gas hydrate samples. Conventional analytical techniques have been studied and modified to more accurately measure these parameters in the laboratory.

5.7.2.4 Work In Progress

- Completed relative permeability experiment design and apparatus
- Used ISCO 500D Syringe pump to inject both gas and water, also giving injection data
- Used coiled (Copper) tubing jacket to maintain desired low temperature
  - Used 50% propylene glycol for coolant.
- Interfaced pump and balance to computer using Dasnet protocol and RS232
- Monitored both injection and production data continuously
- Monitored backpressure by dial pressure gauge and tested for accuracy
- Monitored differential pressure using modulator interfaced with computer
- Successfully achieved preliminary results for consolidated sand cores (Hot Ice #1)
- Successfully achieved preliminary results for consolidated mud cores (Hot Ice #1)

5.7.2.5 Displacement or Unsteady-State Method

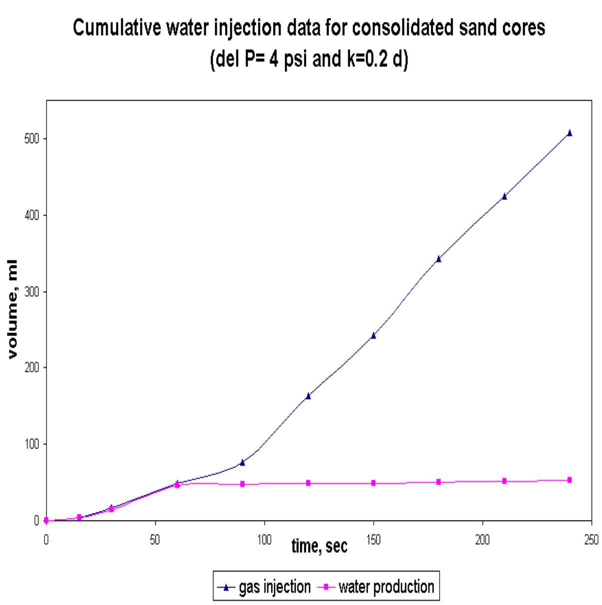
- Water-flood small core sample to irreducible gas saturation
- Gas-flood same core sample
  - Determine gas injection rate for constant pressure drop
  - Collect effluent water fractions in weighing balance
- Develop relative permeability curves from above data, augmented by:
  - Absolute permeability
  - Pore volume of core
  - Gas and water viscosities
- Calculate average fluid saturation in core during core flood from overall material balance
  - Apply graphical techniques (Jones and Roszelle[1]), equivalent to equations of JBN[2], but easier to use and can more accurately evaluate relative permeabilities
  - Alternatively, could calculate average fluid saturation in core using equations successfully applied by JBN[2], but these equations require tedious computation and are subject to error because of the evaluation of derivatives

Currently, there are no generally accepted methods in the industry for the laboratory measurement of porosity, permeability, and relative permeability for a gas hydrate system, nor any published laboratory measurements of permafrost or gas hydrate properties to provide accepted standards for comparison.

Current literature indicates that porosity and permeability of gas hydrate-bearing porous media is very low. Automated data collection using mass flow meters to monitor total (gas plus water) effluent production after gas breakthrough and a gas water separator placed on a electronic balance to monitor water production are used (Figure 14) to achieve the accuracy required for unsteady state relative permeability measurements in a gas hydrate system. The porosity of gas hydrate-bearing porous media is quite low; therefore, the dead volume (inlet, outlet lines, and the ring channel distribution system) of the set-up plays an important role in the displacement tests. The magnitude of the effect of inaccuracies in determining dead volume on gas-water unsteady state relative permeability measurements for low porosity is well documented in literature (Gash, 1991). For our calculation, dead volume is assumed to be water filled at the start of gas injection. The displacement of the water in the dead volume was assumed to be piston-like so that the dead volume was subtracted from the water produced. The Johnson, Bossler, and Neumann (JBN) (Johnson, 1959) is used to calculate relative permeability curves.

5.7.2.6 Results

Experimental results from both consolidated sand and consolidated mud (for variable differential pressure) are presented in this report. The core samples were obtained from the sediments recently cored in the Anadarko Hot Ice #1 well. Selected short core length is approximately 2.5 inches to avoid any gravity effects. The experiment was performed at room temperature with a backpressure of 136 psi.



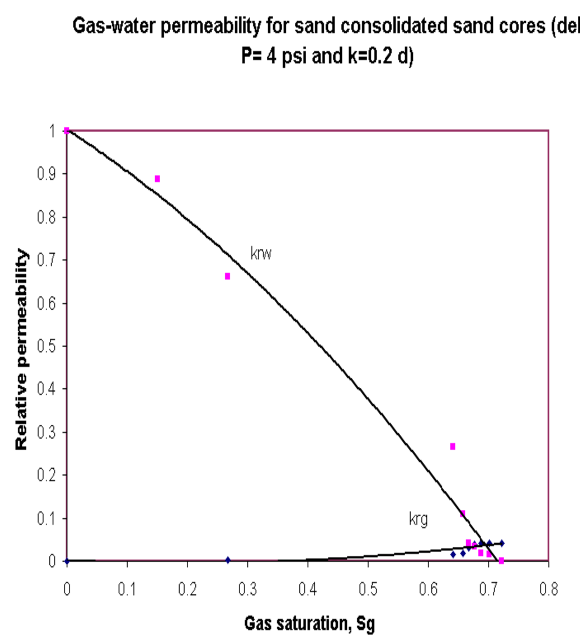


Figure 17: Production data and relative permeability curve for consolidated sand core

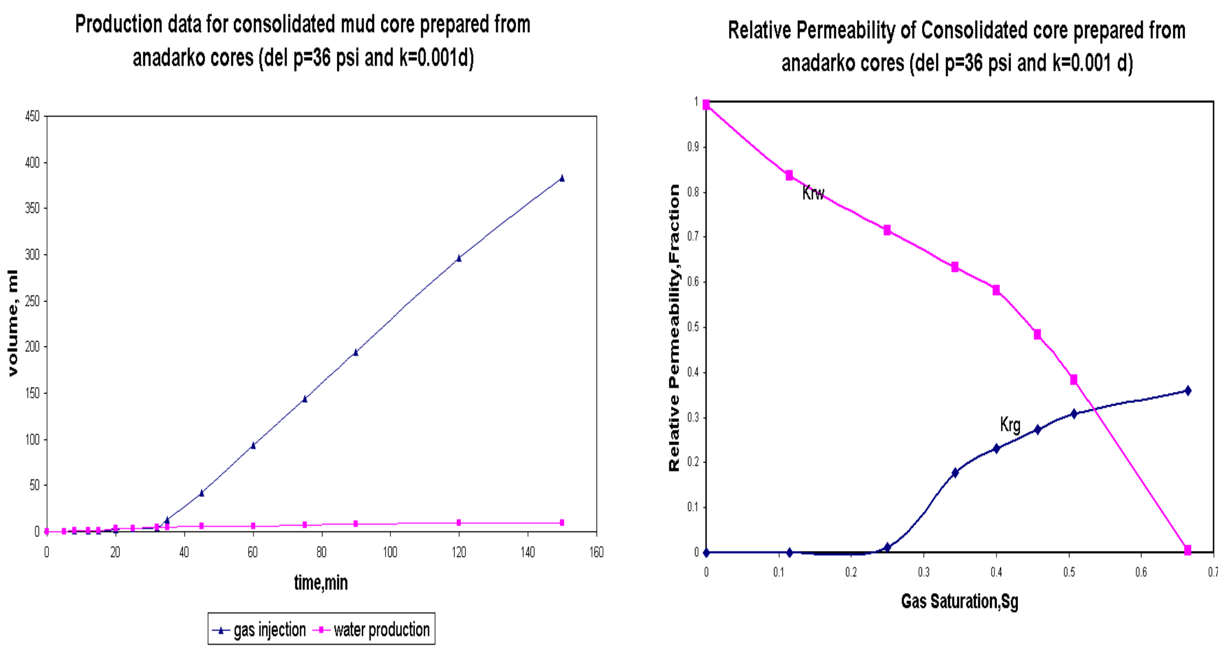


Figure 18: Production and Gas water relative permeability curve for consolidated mud core

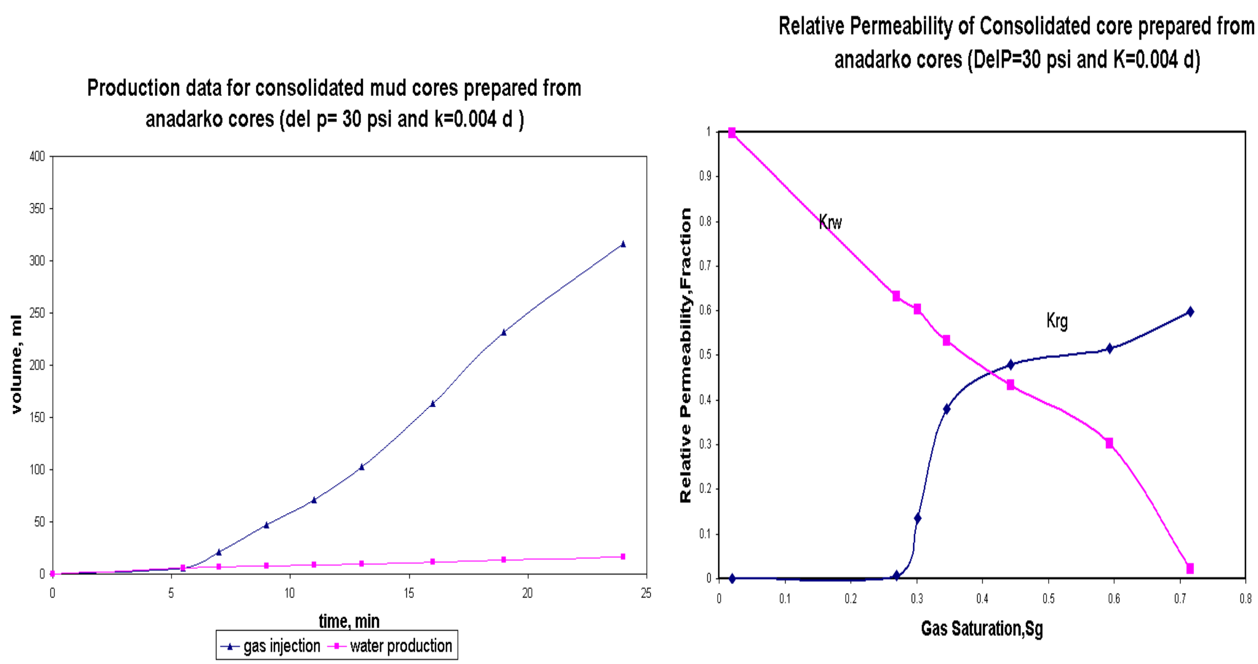


Figure 19: Production and Gas-water relative permeability curve for consolidated mud cores

5.7.2.7 Mathematical Model Development

The continuous flow channel with the largest minimum cross-sectional dimension dominates flow through porous media. The permeability of a porous medium partially saturated with gas hydrate depends critically on where gas hydrate forms in the pore space. The June 2003 Quarterly Technical Report presented some of the models identified in literature and under consideration for developing a gas hydrate system mathematical model.

Also under consideration is a mathematical analog to coalbed methane. Gas can be liberated from gas hydrate-bearing porous media by changing the pressure and/or temperature regime. Investigation of only the depressurization option for gas production from gas hydrate-bearing porous media requires attempts to maintain a constant temperature. Therefore, this alternative focuses on varying pressure with attempts to maintain temperature control.

Mathematical modeling of the porous plate experiment is performed in two stages. The first stage involves the determination of equilibrium coal gas production using a Hertz-Knudsen-Langmuir equation[3] non-linear methane production model. In the second stage, a 1-D. two-phase numerical model, based on the initial and boundary conditions of the experimental constraints, was employed to obtain representative capillary pressure and relative permeability characteristics.

Stage 1: Non-Linear methane gas production model from gas hydrates.

$$J_{\max}(T) = \frac{P_{eq}(T)}{\sqrt{2pMRT}}$$

The Hertz-Knudsen-Langmuir equation (for the rate of gas dissociation) is used to determine the heat flux necessary to keep the sample temperature constant, and thereby maintain this maximum rate of production of gas from the gas hydrate .The full temperature dependence of the gas dissociation rate predicted by equation is known only when the explicit temperature dependence of equilibrium pressure is known (P-T diagram).

Stage 2: Formulation of simulation equations

Requirements include:

- Set of PDE, initial and boundary conditions that accurately model the behavior of our experimental set up.
- Experimental strategies to eliminate the effect of gravity (high flow rates and short core length) and also alleviate the effect of dissociation (for high rates of production)

The simple material balance equation gives:

Water phase:

$$\frac{\partial}{\partial x}\left(\frac{kk_{rw}}{m_w B_w}\frac{\partial p_w}{\partial x}\right) - q_w = \frac{\partial}{\partial t}\left(\frac{f s_w}{B_w}\right)$$

Gas phase:

$$\frac{\partial}{\partial x}\left(\frac{kk_{rg}}{m_g B_w}\frac{\partial p_g}{\partial x}\right)+\frac{\partial}{\partial x}\left(\frac{k_{krw}R_{sw}}{m_g B_g}\frac{\partial p_g}{\partial x}\right)-q_g=\frac{\partial}{\partial t}\left(\frac{fs_g}{B_g}+\frac{fs_w R_{sw}}{B_w}\right)$$

Solving this equation by IMPES and applying experimental boundary condition would result in predicting gas hydrate dissociation and flow characteristics.

5.7.2.8 Future Work

- Refine work on mathematical model of flow equation for anisotropic gas hydrate systems
- Replace nitrogen with helium as overburden gas
- Overcome challenging cooling effect with gas hydrate formation in core holder
- Develop functional relationship between permeability, porosity, structural discontinuities, tortuosity, and fluid parameters such as viscosity

5.8 TASK 8.0: Evaluate Drilling Fluids – UAF

5.8.1 Subtask 8.1: Design Integrated Mud System for Effective Drilling, Completion and Production Operations

- Design fully integrated mud system for permafrost and gas hydrate-bearing section
- Assess mud contamination risk
- Evaluate mud chiller system for Alaska North Slope, such as one used in Mackenzie Delta Mallik research program

5.8.1.1 Literature Review Emphasis

- Gas hydrate inhibitors (thermodynamic, kinetic and low dosage gas hydrate inhibitors)
- Application of anti-agglomerants gas hydrate inhibitors
- Scale formation and prevention in the presence of gas hydrate inhibitors
- Thermal and rheological properties of drilling fluids as a tool to design mud chiller
- Formation damage characterization techniques

5.8.1.2 Mud Cooler to Enhance Drilling and Completion Operations

Methane hydrate is stable within a defined pressure and/or low temperature environment. An effective method to prevent drilling and/or completion problems caused by dissociation of in-situ natural methane hydrates during these operations involves using chilled drilling fluids, thus maintaining the low temperatures required for stable gas hydrates. Mud coolers used in Canada (Figure 19) were simple heat exchangers using cold seawater, plentiful in arctic conditions. Ideal for arctic drilling, the commercially available mud cooler offers easy installation, full temperature control, satellite communications, an easy operation interface, modular design, and the ability to set up near active tanks. During drilling operations, use of a mud chiller enhances wellbore stability and environmental safety within permafrost and gas hydrate-bearing sections. Long-exposure to these sections during drilling operations can lead to significant well control problems if the temperature stability is not maintained within gas hydrate-bearing sections.

Indirect advantages of chilled mud include better formation contact and more accurate readings of logging tools due to an in-gauge hole and prevention of large washouts. The heat exchangers appear to offer the best solution. They are inexpensive, of very limited size, and not prone to clogging. The technology is well known, but not yet commonly used during drilling operations. Maintenance of heat exchanger mud coolers is very low (Maury V.; 1995). Sasaki K., et. al. have studied thermal and rheological properties of drilling fluids to estimate the heat transfer rate at casing pipe. The current strategy for penetration of gas hydrate-bearing sections involves rapidly penetrating and casing off the section. However, resource exploitation of the gas hydrate-bearing section would benefit from an in-gauge borehole without major washouts of the gas hydrate-bearing reservoir intervals during expected longer exposure to drilling and completion fluids.

Commercially available mud coolers have following features:

- Water reservoir that maintains a constant water level through the use of a float device and circulation pump
- Continuous operation assurance with dual design of the upper and lower cooling tube bundles for enhanced performance and service life
- Internal sprinkler system to evenly distribute cooling water over the bundles
- Multi-fan system to pull air upward throughout the Geo-Cooler and over the cooling tube bundles
- 5” x 6” centrifugal pump with filtering capabilities to maintain flow rate of drilling mud/fluids through the system.
- Operator-selected temperature regulation system that dials in and maintains desired temperature
- Eliminator system deflectors that ensure water travels downward and air travels upward
- Ability to cool heavy drilling fluids over 18 ppg
- Master control panel for all electrical functions
- Multiple available units
- Shipped complete and ready to install in hours

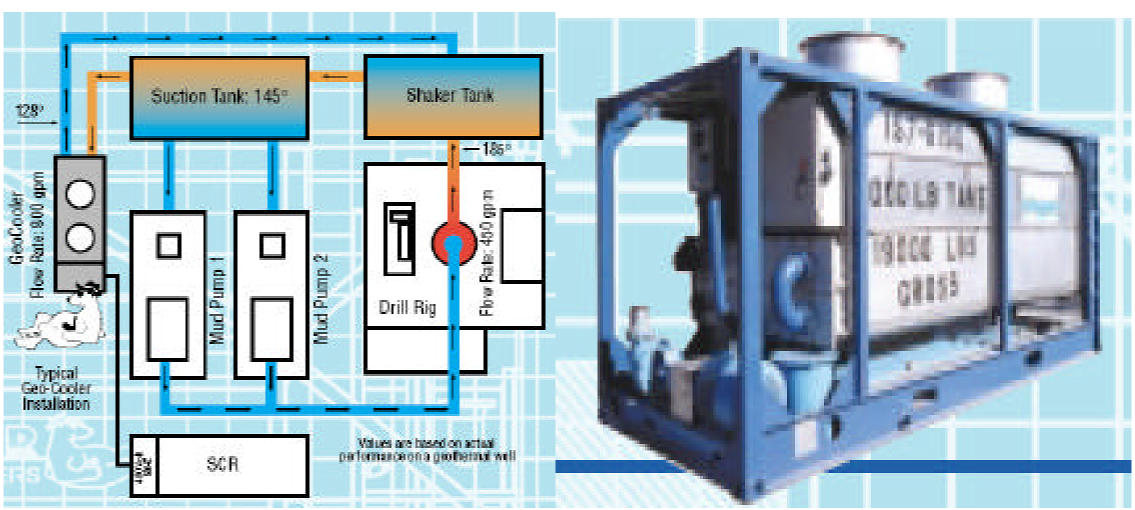


Figure 20: Mud Cooling System (After, Drill Cool Systems, Inc.)

5.8.1.3 Future Plans

Future work will assess incompatibility between brine and injection water in the drilling mud simulator. Current Alaska North Slope drilling fluid properties may change if circulated through a mud chiller.

5.8.2 Subtask 8.2: Assess Formation Damage: Testing, Analysis and Interpretation

5.8.2.1 Future Work Plans

- Investigate formation damage potentials by subjecting the reservoir core samples to flow at near-in situ conditions in the laboratory
- Test laboratory core flow under repeatable conditions
  - Obtain actual or representative drilling mud samples (Alaska North Slope and/or Mackenzie Delta, Canada)
  - Obtain actual or representative formation fluid samples (methane gas and water)
  - Obtain actual or representative reservoir sand and mud cores
  - Conduct experiments under similar temperature and pressure conditions expected during field operations.
- Build apparatus to investigate and maintain both overbalanced and underbalanced drilling conditions to alleviate invasive formation damage (Figure 20)
- Overcome many deficiencies associated with previous formation damage test procedures
  - Use recently developed technology to conduct full reservoir condition dynamic leak off experiments and evaluate the action of whole drilling fluids on the formation
- Design proposed apparatus to enable testing of both reservoir stressed and restored core
  - Subject core samples to initial baseline flow of reservoir gas (methane)
    - Measure original, undamaged permeability
  - Circulate whole drilling fluid (with drill solids, granular bridging agents, etc.) across core samples
    - Investigate various over- and under-balanced mud conditions
    - Measure changing permeability to methane gas over extended time periods (10-12 hours) for specified drilling fluid flow
    - Determine the times at which significant permeability changes are induced
    - Investigate and measure other drilling parameters, including fluid leak-off, filter cake build up, physical depth of invasion of filtrate and solids

5.8.2.2 Equipment Procurement Plans

- Build an underbalanced drilling apparatus to assess formation damage
- Design apparatus to maintain a dynamic underbalanced condition
  - flow either gas or oil and turbulently circulate water-based (or oil-based) drilling fluid of interest across the core face
  - Obtain continuous permeability measurements
- Employ special core holder to avoid experiment pitfalls

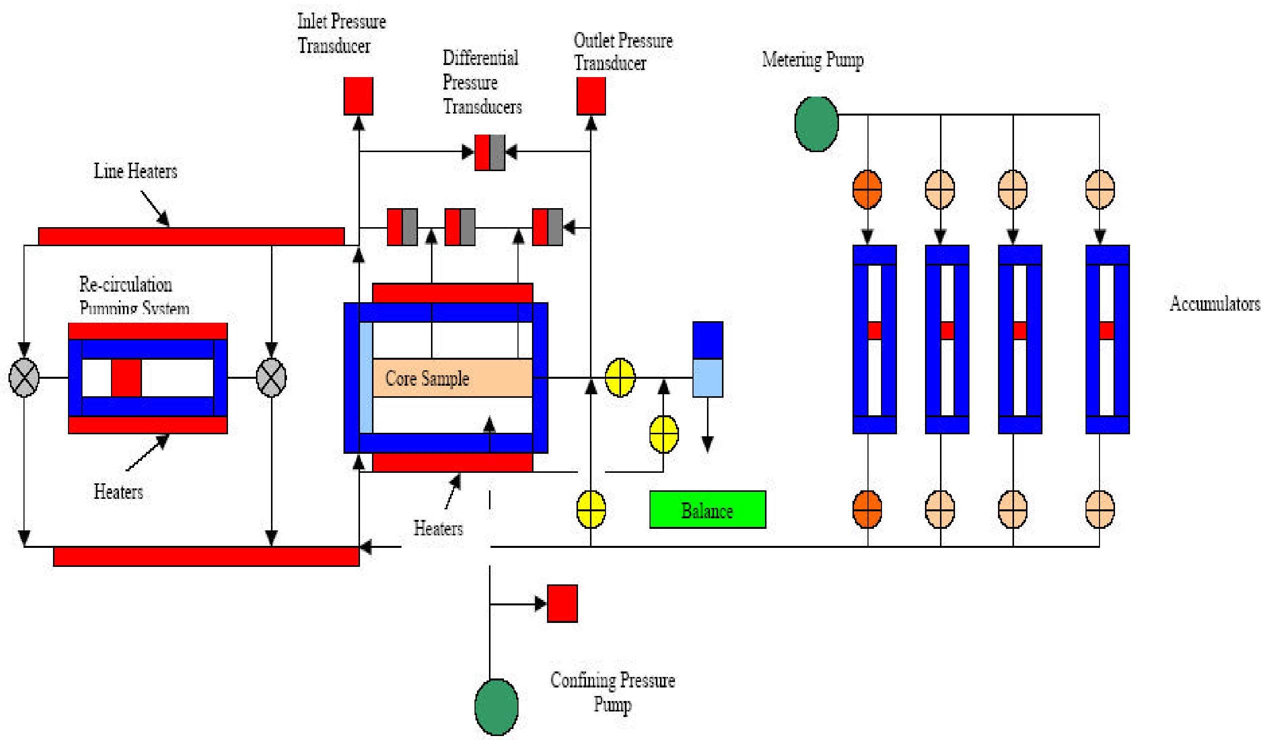


Figure 21: Proposed Apparatus Set-up for Formation Damage Studies

5.8.2.2.1 Core Holder Design

Traditional core-holders cause significant turbulence at the mud inlet and mud outlet ports. This turbulence may cause excess mud invasion of core in the rubber sleeve and can create boundary flow effects around the core. A special core-holder, the Dynamic Filtration Core Holder, can minimize possible turbulence and boundary flow effects by maintaining a maximum mud flowing pressure of 2500 psi and passing mud flow across the core face, thus preventing curved fluid pathways.

5.8.2.2.2 Core Holder Diameter

Depending on reservoir heterogeneity, either plug (3.0 cm OD) or full diameter (up to 10.16 cm OD) core samples can be utilized (Crowell, E.C. et al.; 1991). Restored-state or native-state core is desirable to preserve wettability as fluid leakoff rates can be significantly influenced by formation wettability. The system is applicable to oil or gas reservoirs and is designed with a twin backpressure regulation system, which allows any type of overbalanced or underbalanced operating condition.

Anadarko Petroleum Corporation recently cored analogous sedimentary deposits in their ANS "Hot Ice-1", located approximately two miles south of the present boundary of Kuparuk River Unit and five miles east of the Meltwater development, in NW/4, Sec. 30-T9N-R8E, Umiat Meridian. This core material will provide suitable experimentation substrate. The 3.4 inch OD cores are available at UAF. The exploratory well was cored continuously from 107 ft. to a current total depth of 1,400 feet. Drillout to below 2,600 feet is expected by Spring 2004.

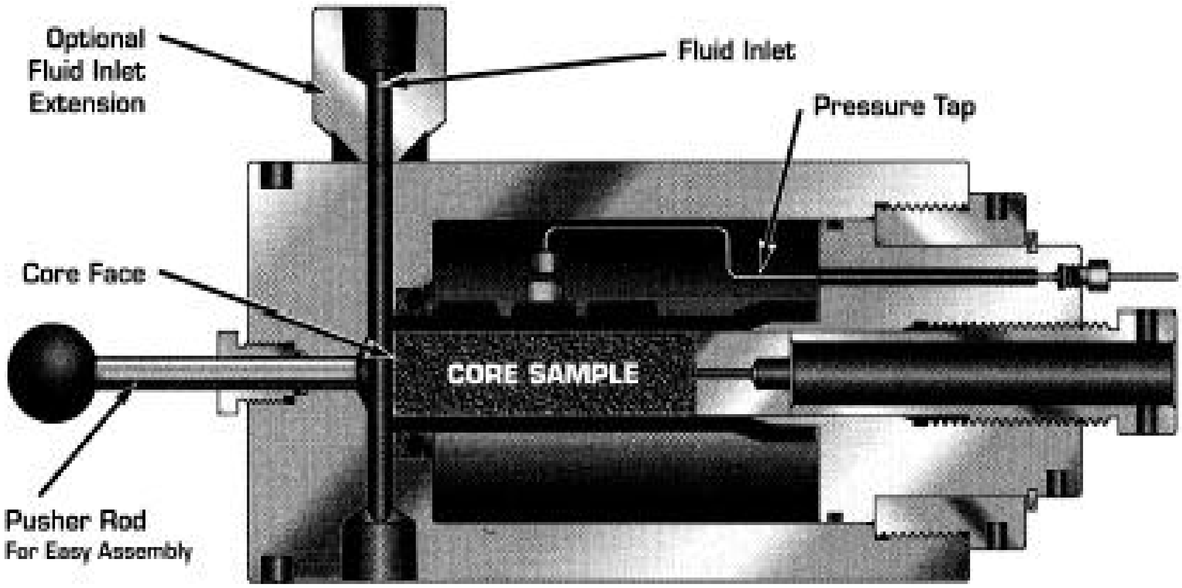


Figure 22: Schematic of Dynamic Filtration Core Holder (After, Temco, Inc.)

5.8.2.2.3 Mud Flow Line

In the Mackenzie Delta 2L-38 well program, a KCl/polymer/lecithin mud system was utilized. The basic composition of the mud used in the main hole intervals consisted of 50 kg/m3 of KCl (antifreeze agent and shale inhibitor), 1-3 kg/m3 of Xanvis (viscosifiers), 0.5 kg/m3 of KOH (pH control), 6 L/m3 of lecithin (62% Drilltreat; gas hydrate promoter), 10 kg/m3 of Dextrid LT (filtration control), 0.3 kg/m3 of Na2SO3, and barite (weighting material). Considering the solid particles and viscosity of this mud composition, we plan to keep 3/8 inch of diameter of mudflow line (Dallimore, S.R. et al.; 1999). Kutasov has suggested that salted drilling mud prevents casing collapse in permafrost; therefore, use of NaCl instead of KCl can also be assessed.

5.8.2.2.4 Facility to confirm gas hydrate formation

Although not a new technology, pressure tapped cores have been utilized more extensively in recent years to evaluate physical depth of formation damage, particularly associated with the invasion and entrainment of solids or acidization and/or precipitation-induced damage (Bennion, D.B. et al.; 1995, 1996). The use of pressure taps allows the operator to evaluate sectional permeabilities and thereby compare the original permeability determined in an undamaged situation to a transient permeability profile which may change as a function of time due to the entrainment of aqueous fluids, solids, potentially damaging fluid-clay interactions, and/or the formation of precipitates, etc. These tests are particularly useful for long-term quantifying of the speed and rapidity of formation damage. The pressure drop at a particular point on the core might confirm the formation of gas hydrate (Chen, W. et al.; 1998).

5.8.2.2.5 Pressure differential transducer

Pressure differential measurements across the core sample, to facilitate permeability calculations, will be conducted through the use of a DP15-60-V-1-S-4-C Validyne Transducer and CD23-A-1-D-1-C indicator. The transducer has a range of 0 to 1250 psi to facilitate accurately measuring a wide range of pressure differentials, which might occur over the course of a displacement test.

5.9 TASK 9.0: Design Cement Program – UAF

5.9.1 Task 9 Future Work

- Continue literature survey and assess current permafrost cements
- Work with AETDL and DOE to fund cooperative research program with Argonne National Lab (ANL) to study efficacy of Ceramicrete as arctic conditions and chilled drilling cement
    - Proposal presented to AETDL review panel in July 2003
    - Proposal ranked second and to be forwarded to NETL for funding by AETDL
    - Project co-funding and participation commitments by Bindan Corporation (Ceramicrete manufacturer) and BJ Drilling (mud company)
- Design experiments to assess cements and conduct preliminary experiments at ANL

5.10 TASK 10.0: Study Coring Technology – UAF

5.10.1 Coring Technology Summary

Analyses of reservoir core within ANS methane hydrate-bearing sediments may help determine whether or not gas hydrates can become an economically feasible source of energy. Therefore, phase 2 project operations may include acquisition, recovery, transportation, and preservation of an undisturbed pressurized core of methane hydrate-bearing sediments. Alternatively, conventional core may provide sufficient information. However, non-preservation of in-situ pressures may make conventional coring less desirable for the purposes of this research project. Therefore, special pressurized coring systems must also be considered for recovery of gas hydrate-bearing sediments. These systems are designed for low temperature use, and have the capability to maintain natural gas hydrate pressures and/or temperatures. The various methods for recovering, preserving, and transporting gas hydrate cores at in-situ conditions were reviewed in the June 2003 Quarterly Report.

5.10.2 Future Work

- Continue literature survey
- Assess coring technologies and recommend best core methods for ANS application

5.11 TASKS 11.0 and 13.0: Reservoir Modeling and Project Commerciality and Progression Assessment – UAF, BP, LBNL, Ryder Scott

5.11.1 Activities Conducted during Secondment to LBNL

LBNL reservoir model training began with review of the standard TOUGH2 training course. The TOUGH2 reservoir simulator is used with various equations of state modules, depending on modeling requirements. EOS1 is the most basic and simulates flow of water through porous media. After study of the TOUGH2 documentation, a small executable module was used for training. Deliberate mistakes were included in the data files to test knowledge of the system. Different runs were made using the different grid geometries generated within TOUGH2. Media and fluid properties were varied and the differing simulation results were noted and explained. Various sinks and sources of both fluid and energy were added.

Training progressed to EOS3, a water-air, two component, and two phase simulation. With the extra component, the initial parameter data were scrutinized in more detail. The effects of inactive boundary blocks (which can act as infinite energy sinks) were also investigated.

T2VOC incorporates a single organic compound into the system. The presence of the organic necessitates significant additional data in the input file. Again, numerous sample problems were run, each time making various modifications to the input variables and explaining the differing effects on the output results.

The most advanced publicly released module is the TMVOC. The EOSHYDR2 module models the dissociation of methane hydrate in geologic formations. The current version of EOSHYDR2 uses the TMVOC module with necessary code changes and additions for the heat and mass balance equations for gas hydrates. Although the internal code has been changed within TMVOC, the output codes have not yet been changed. Therefore, current output data is incorrectly labeled. This results in a high-potential for user errors and requires debugging. In addition, calibration of EOSHYDR2 using data from the 2002 Mallik project gas hydrate testing results is ongoing. Neither EOSHYDR2, nor 2002 Mallik testing results are available to parties outside the development team at this time. Beta release of EOSHYDR2 for testing by this project is expected by January 2004. Mallik testing results should be publicly released in December 2003.

Challenges of accurately modeling gas hydrate dissociation were discussed. For example, field studies may indicate changes in the depth of the gas hydrate-free gas interface. Using the current version of EOSHYD2, it is not possible to simply modify this depth. The initialized conditions, such as temperature and thermal gradients would require adjustment to obtain the correct result. The settings that provided the correct fluid contact depth may not completely align with a newly measured fluid contact depth..

The leverage of different variables and their range of uncertainty can dramatically affect reservoir simulation results and the calculation of the amount of gas dissociation from gas hydrate. Examples may include porosity changes, relative permeability relationships, and fluid saturation variance. These and other leveraging variables require modeling in various development scenarios to determine the primary leveraging variables and how their ranges of uncertainty will affect the model initialization and final calculations. Specific field tests can then be designed to help better define certain leveraging variables and to reduce their range of uncertainty.

5.11.2 Future Work Plans

- Await Beta release of EOSHYDR2 reservoir simulation module in December – January
- Continue study of TOUGH2 generic features using foundation program TMVOC
- Consider independent grid initialization using alternative grid generation tool (Meshmaker)
- Collect available data to assist reservoir and fluid characterization
- Collaborate with UA to calibrate characterization studies with laboratory research results

5.11.3 Scope of Work

Interim simulation studies will allow work to progress prior to Beta release of the EOSHYDR2 module of TOUGH2. Modeling gas dissociation from gas hydrate, where a regional free gas zone underlies a gas hydrate zone, can be accomplished using a commercial 'off the shelf' simulation package for the free-gas section in combination with kinetic and mass balance calculations developed during previous studies at the University of Alaska Fairbanks.

STARS is a multi-component, multi-phase, thermal simulator developed by the Computer Modeling Group (CMG). It is a comprehensive package and can adequately model all the geological characteristics within the simulation area. Current UAF studies include an unsteady-state, 2-D radial model developed to model dissociation of gas hydrates, based on moving boundary "Stefan" problems. Another simulation involves a mass balance analytical model incorporating inflow performance and the kinetics of gas hydrate decomposition. Use of ProCast in association with collaborative reservoir modeling studies with Ryder Scott Company will also be investigated.

The scope of work includes reservoir model initialization using the input data supplied to LBNL for the preliminary modeling study of the Eileen accumulation using EOSHYDR. Output from the interim modeling work can be compared to the results from the LBNL study (already provided to UAF) to check that the processes have been modeled correctly.

The flexibility of the STARS or ProCast package will then be used to model the geometric and geologic characteristics of the study area. The model will incorporate currently available data, simulate various development scenarios, and assess various conventional and non-conventional drilling/completion technologies. Interim simulation results from STARS or ProCast can be compared/contrasted to EOSHYDR2 results.

5.12 TASK 12.0: Select Drilling Location and Candidate – BP, UA

No significant progress was made in this task during the report period.

6.0 CONCLUSION

Interim conclusions only are presented at this stage in the research program. Establishing this collaborative research agreement culminates nearly three decades of hundreds of well penetrations of methane hydrate during ANS oil production operations following the first dedicated gas hydrate coring and production testing in NW Eileen State – 02, drilled in 1972 within the Eileen gas hydrate trend by Arco and Exxon. During this time, methane hydrates were 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 created the industry – government alignment necessary to reconsider the resource potential of the potentially huge (40 – 100 TCF in-place) unconventional ANS methane hydrate accumulations beneath existing production infrastructure.

The BPXA – DOE collaborative research project is designed to enable industry and government to make informed decisions regarding the resource potential of this ANS methane hydrate through comprehensive regional shallow reservoir and fluid characterization utilizing 3D seismic data, implementation of methane hydrate experiments, and design of techniques to support potential methane hydrate drilling, completion, and production operations.

The results of the collaborative BPXA-LBNL pre-Phase 1 scoping reservoir model and economics study (presented in the March 2003 Quarterly report and recent technical conferences) demonstrate first-ever potential commerciality of gas production from gas hydrate across a broad regional contact from adjacent free gas depressurization. This collaborative research project will verify the size of the potential resource, determine the extent of reservoir/fluid compartmentalization, and validate potential production techniques.

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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
AETDL	Alaska Energy Technology Development Laboratory
ANL	Argonne National Laboratory
ANN	Artificial Neural Network
ANS	Alaska North Slope
AOGCC	Alaska Oil and Gas Conservation Commission
AVO	Amplitude versus Offset (seismic data analysis technique)
ASTM	American Society for Testing and Materials
BLM	U.S. Bureau of Land Management
BP	British Petroleum (commonly BP Exploration (Alaska), Inc.)
BPXA	BP Exploration (Alaska), Inc.
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)
GEOS	UA Department of Geology and Geophysics
GOM	Gulf of Mexico (typically referring to Chevron Gas Hydrate project JIP)
GR	Gamma Ray (well log)
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
KRU	Kuparuk River Unit
LBNL	Lawrence Berkeley National Laboratory
MGE	UA Department of Mining and Geological Engineering
MPU	Milne Point Unit
NETL	National Energy Technology Laboratory
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
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
VSP	Vertical Seismic Profile

9.0 APPENDICES

9.1 APPENDIX A: Project Task Schedules and Milestones

9.1.1 U.S. Department of Energy Milestone Log

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	12/02	Subcontracts Completed Research Management ongoing
Task 2.0	Provide Technical Data and Expertise	MPU: 12/02 PBU: * KRU: *	MPU: 12/02 PBU: * KRU: *	Ongoing, See Technical Progress Report Description
Task 3.0	Wells of Opportunity Data Acquisition	Ongoing to 12/03-10/04**	Ongoing	Ongoing, See Technical Progress Report Description
Task 4.0	Research Collaboration Link	Ongoing to 12/03-10/04**	Ongoing	Ongoing, See Technical Progress Report Description
Subtask 4.1	Research Continuity	Ongoing	Ongoing	
Task 5.0	Logging and Seismic Technology Advances	Ongoing to 12/03-10/04**		Ongoing, See Technical Progress Report Description
Task 6.0	Reservoir and Fluids Characterization Study	10/04**		Interim Results to also be presented
Subtask 6.1	Characterization and Visualization	10/04**		Interim Results to also be presented
Subtask 6.2	Seismic Attributes and Calibration	10/04**		Interim Results to also be presented
Subtask 6.3	Petrophysics and Artificial Neural Net	10/04**		Interim Results to also be presented
Task 7.0	Laboratory Studies for Drilling, Completion, Production Support	6/04**		
Subtask 7.1	Characterize Gas Hydrate Equilibrium	6/04**		
Subtask 7.2	Measure Gas-Water Relative Permeabilities	6/04**		
Task 8.0	Evaluate Drilling Fluids	6/04**		
Subtask 8.1	Design Mud System	11/03		
Subtask 8.2	Assess Formation Damage	5/04**		

Task 9.0	Design Cement Program	10/04**		
Task 10.0	Study Coring Technology	2/04**		
Task 11.0	Reservoir Modeling	10/04**		Interim Results to also be presented
Task 12.0	Select Drilling Location and Candidate	10/04**		
Task 13.0	Project Commerciality & Progression Assessment	10/04**		Interim Results to also be presented

* Date estimate dependent upon industry partner agreement for seismic data release

** Anticipated completion dates beyond 12/31/03 will require no-cost (and possibly some-cost) time-extension to complete 2-year Phase 1 program. Time extension should be completed by end-November 2003.

9.1.2 U.S. Department of Energy Milestone Plan

(DOE F4600.3)

DOE F 4600.3#

U.S. DEPARTMENT OF ENERGY FEDERAL ASSISTANCE MILESTONE PLAN

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 12/31/05*

6. Identification Number	7. Planning Category (Work Breakdown Structure Tasks)	8. Program/Project Duration (Currently illustrates 2002-2004) O N D J F M A M J J A S O N D J* F* M* A* M* J* J* A* S*	9. Comments (Primary work Performer)
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, RyderScott
Task 11.0	Reservoir Modeling	>>>>------------------------>>>>>>>>>>---!------------->>>>>>>>>>>>>>>>>>>>>>>>>	UAF
Task 12.0	Drilling Candidate Selection	>>>------ ----->!>>>>------- ---->>>>>>>>	BPXA, UA
Task 13.0	Commerciality Assessment	>>>>>>-------------------------------->>!>>>>>------------------------->>>>>>>>	BPXA, UAF

10. Remarks * Official Contract Date 10/22/02; Funded pre-Phase 1 from 10/01-10/02 at reduced cost levels. Phase I project (from 10/01 through 12/03) time-extension is in-progress through 10/04 due to 10/21/02 project contract date and 2-year Phase I research program.
Explanation of Symbols: (> = Major Task Work); (- = Minor Task Work); (! = current time).
Additional significant milestones presented in October 2003 technical progress report.

11. Signature of Recipient and Date	12. Signature of U.S. Department of Energy (DOE) Reviewing Representative and Date