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Results from the (1) Data Collection Workshop, (2) Modeling Workshop and (3) Drilling and Coring Methods Workshop as part of the Joint Industry Participation (JIP) Project to Characterize Natural Gas Hydrates in the Deepwater Gulf of Mexico

Topical Report

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Edited by: **Stephen A. Holditch**
Schlumberger Fellow

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ABSTRACT

In 2000, Chevron began a project to learn how to characterize the natural gas hydrate deposits in the deepwater portions of the Gulf of Mexico. A Joint Industry Participation (JIP) group was formed in 2001, and a project partially funded by the U.S. Department of Energy (DOE) began in October 2001. The **primary objective** of this project is to develop technology and data to assist in the characterization of naturally occurring gas hydrates in the deepwater Gulf of Mexico. These naturally occurring gas hydrates can cause problems relating to drilling and production of oil and gas, as well as building and operating pipelines. Other objectives of this project are to better understand how natural gas hydrates can affect seafloor stability, to gather data that can be used to study climate change, and to determine how the results of this project can be used to assess if and how gas hydrates act as a trapping mechanism for shallow oil or gas reservoirs.

As part of the project, three workshops were held. The first was a data collection workshop, held in Houston during March 14-15, 2002. The purpose of this workshop was to find out what data exist on gas hydrates and to begin making that data available to the JIP. The second and third workshop, on Geoscience and Reservoir Modeling, and Drilling and Coring Methods, respectively, were held simultaneously in Houston during May 9-10, 2002. The Modeling Workshop was conducted to find out what data the various engineers, scientists and geoscientists want the JIP to collect in both the field and the laboratory. The Drilling and Coring workshop was to begin making plans on how we can collect the data required by the project's principal investigators.

All three workshops were successful. The attendance was 90+ at the Data Collection Workshop and 80+ at the combined modeling, drilling and coring workshop. The workshops were organized to have keynote sessions, breakout sessions, and report out sessions. Specific goals were set and deliverables were expected of the breakout groups. This report provides a detailed account of the three workshops. More information can be found on the JIP website.

http://qpext.chevrontexaco.com/QuickPlace/wwuexpl_gashydrates/Main.nsf?OpenDatabase.

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1.0 INTRODUCTION

In 2000 Chevron Petroleum Technology Company began a project to learn how to characterize the natural gas hydrate deposits in the deepwater portion of the Gulf of Mexico. Chevron is an active explorer and operator in the Gulf of Mexico, and is aware that natural gas hydrates must be better understood to operate safely in deepwater. In August 2000 Chevron, working closely with the National Energy Technology Laboratory (NETL) of the United States Department of Energy (DOE), held a workshop in Houston, Texas, to define issues concerning the characterization of natural gas hydrate deposits. Specifically, the workshop was meant to clearly show where research, the development of new technologies, and new information sources would be of benefit to the DOE and to the oil and gas industry in defining issues and solving gas hydrate problems in deepwater.

On the basis of the workshop held in August 2000, Chevron formed a Joint Industry Participation (JIP) group to write a proposal and conduct research concerning natural gas hydrate deposits in the deepwater portion of the Gulf of Mexico. The proposal was submitted to NETL on April 24, 2001, and Chevron was awarded a contract on the basis of the proposal.

The title of the project is

"Characterizing Natural Gas Hydrates in the Deepwater Gulf of Mexico: Applications for Safe Exploration and Production Activities".

1.1 Objectives

The **primary objective** of this project is to develop technology and data to assist in the characterization of naturally occurring gas hydrates in the deepwater Gulf of Mexico. These naturally occurring gas hydrates can cause problems relating to drilling and production of oil and gas, as well as building and operating pipelines. Other objectives of this project are to better understand how natural gas hydrates can affect seafloor stability, to gather data that can be used to study climate change, and to determine how the results of this project can be used to assess if and how gas hydrates act as a trapping mechanism for shallow oil or gas reservoirs.

1.2 Project Phases

The project is divided into phases. **Phase I** of the project is devoted to gathering existing data, generating new data, and writing protocols that will help the research team determine the location of existing gas hydrate deposits. During **Phase II** of the project, Chevron will drill at least 3 data collection wells to improve the technologies required to characterize gas hydrate deposits in the deepwater Gulf of Mexico using seismic, core and logging data.

1.3 Research Participants

In 2001, Chevron (now ChevronTexaco) organized a Joint Industry Participation (JIP) group to plan and conduct the tasks necessary for accomplishing the objectives of this research project. The original members of the JIP were Chevron, Schlumberger, Phillips, Conoco, and Halliburton. Recently, the Minerals Management Service (MMS), TotalFinaElf, and Japan National Oil Corporation have agreed to participate in the JIP. Additional corporations and organizations are still inquiring about joining the JIP.

1.4 Research Activities

The research activities began officially on October 1, 2001; however, during the first few months, very little activity took place other than the preparation of documents within the JIP and the DOE, and the organization of Technical Teams by the JIP participants.

<u>Technical Team Organizational Workshop</u>: In December 2001, a team organization workshop was held at the offices of ChevronTexaco in Houston. Phase I of this research project has been divided into 12 Tasks. The 12 Tasks are (1) Research Management Plan, (2) Project Management and Oversight, (3) Data Collection and Organization, (4) Development of New Gas Hydrate Sensors, (5) Development of Wellbore Stability Model, (6) Seismic Modeling and Analysis, (7) Kenetics and Thermodynamics Analyses, (8) Determine Data Requirements for GeoModels, (9) Develop Drilling and Coring Test Plans, (10) Core Handling and Core Tests, (11) Review Data and Select Locations of 3 Field Test Sites, (12) Conference – Field Testing.

The JIP has formed 4 technical teams. The Seafloor Stability Team is responsible for planning and conducting Tasks 4, 8, and 11. The Drilling and Coring Team is responsible for Tasks 5, 9, and 10. The Hydrates Characterization Team is responsible for Tasks 3, 6, and 7. A fourth team, called the Technology Transfer Team, is in charge of writing the technical reports and papers to describe the research and for planning Task 12.

Data Collection Workshop: A data collection workshop was held in Houston during March 14-15, 2002. The objective of the workshop was to bring together the scientists and engineers who have worked the most on natural gas hydrate technology to obtain feedback on the quantity and the quality of the data that currently exist in the public domain and in industry. Specifically, the JIP wanted to know what data are currently available for use by the JIP, where are the gaps in the existing data, and how can we build a data base or Website to allow general access to the data that are currently available to the JIP and to the public in general. This workshop also allowed prospective contractors to attend so they could better understand the objectives of the research project, so when requests for proposals go out later in 2002, the contractor community will better understand the objectives of the JIP. Over 90 persons attended the workshop from a variety of organizations. A complete documentation of the workshop can be found on the JIP Website.

http://qpext.chevrontexaco.com/QuickPlace/wwuexpl_gashydrates/Main.nsf?OpenDatabase.

Geoscience/Reservoir Modeling Workshop and Drilling/Coring Workshop: The second and third workshops were held simultaneously in Houston during May 9-10, 2002. The purpose of the Modeling Workshop was to find out what data the geoscience and engineering communities need to run their models – regardless of the type of model. We know that there are geophysical models, geological models, drilling models, wellbore stability models, geomechanical models, reservoir models, and possibly other models that various engineers and geoscientists wish to use to investigate natural gas hydrate deposits. The JIP needs to develop an understanding of what data are required by the modeling community, so that when we go to the field, we know what data we need to collect.

The Drilling and Coring Workshop was designed to discuss the state-of-the-art in drilling through, coring and testing wellbores that encounter natural gas hydrates in deepwater. The results of this workshop will lead to protocols and plans that will be used in Phase II of this research project. More details concerning the results from these two workshops can be found at the JIP website.

1.5 Purpose of This Report

The purpose of this technical report is to present the results from the two workshops that were recently held in Houston. The **Data Collection Workshop** was held March 14-15, 2002, and the detailed report compiled by The Energy Forum, LLC, can be found on the JIP website. The **Modeling, Measurements, and Sensors Workshop** was held simultaneously with the **Drilling, Coring, and Core Analysis Workshop** on May 9-10, 2002, and the detailed report compiled by The Energy Forum, LLC, can be found on the JIP website. The link to the JIP website is as follows:

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2.0 EXECUTIVE SUMMARY

Chevron formed a Joint Industry Participation (JIP) group to write a proposal and conduct research concerning natural gas hydrate deposits in the deepwater portion of the Gulf of Mexico. The proposal was submitted to NETL on April 24, 2001, and Chevron was awarded a contract on the basis of the proposal.

The title of the project is

"Characterizing Natural Gas Hydrates in the Deepwater Gulf of Mexico: Applications for Safe Exploration and Production Activities".

The **primary objective** of this project is to develop technology and data to assist in the characterization of naturally occurring gas hydrates in the deepwater Gulf of Mexico. **Other objectives** of this project are to better understand how natural gas hydrates can affect seafloor stability, to gather data that can be used to study climate change, and to determine how the results of this project can be used to assess if and how gas hydrates act as a trapping mechanism for shallow oil or gas reservoirs.

The project is divided into phases. **Phase I** of the project is devoted to gathering existing data, generating new data, and writing protocols that will help the research team determine the location of existing gas hydrate deposits. During **Phase II** of the project, Chevron will drill 3 data collection wells to improve the technologies required to characterize gas hydrate deposits in the deepwater Gulf of Mexico using seismic, core and logging data.

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A website has been developed to house the data and information that were collected in the Data Collection Workshop, as well as other items submitted during the course of this research endeavor. The link to the JIP website is as follows:

http://qpext.chevrontexaco.com/QuickPlace/wwuexpl_gashydrates/Main.nsf?OpenDatabase.

The first workshop was the Data Collection Workshop that was held in Houston March 14-15, 2002. The purpose of this workshop was to find out what data concerning natural gas hydrate deposits in the deepwater portion of the Gulf of Mexico was in the public domain and could be used by the JIP. The workshop also tried to identify data that would be available for use by the JIP that was not necessarily in the public domain.

The second and third workshops were held simultaneously in Houston on May 9-10, 2002. The Modeling, Measurements and Sensors Workshop was designed to find out exactly what the various engineering and geoscience modelers wanted from the JIP field data collection effort. The Drilling, Coring and Core Analysis Workshop was designed to begin the process of determining how the JIP can go about collecting the data that the modelers and scientists desire.

Thus, the three workshops were designed to (1) inventory the data currently available on naturally occurring gas hydrates in the deepwater Gulf of Mexico, (2) determine what additional data needs to be collected for the modelers and scientists, and (3) determine how to collect the data.

2.1 The Data Collection Workshop

The Data Collection Workshop was held to determine what data are available concerning natural gas hydrate deposits in the deepwater Gulf of Mexico. The specific goals of the Data Collection Workshop were as follows:

1) To develop an understanding of the safety issues involved in drilling and operating in marine sediments containing naturally occurring hydrates through case histories;

2) To determine what is known and what needs to be known for accurate detection and seismic interpretation of hydrate bearing sediment zones using seismic, geochemical, well logging, well testing and drilling data;

3) To determine what is known and what needs to be known about the physical, thermo-chemical, and biogeochemical properties of hydrate bearing sediments to accurately evaluate and model sediment stability;

4) To assimilate data on naturally occurring hydrates in the Gulf of Mexico;

5) To gather all data in the literature, as well as from public and private sources that pertain to naturally occurring hydrates in deepwater Gulf of Mexico;

6) To develop a preliminary format and content for a data base to be used by the JIP to store collected data and to select drilling sites in Phase II of the project; and

7) To identify individuals and institutions that can assist in obtaining the necessary data and technology to meet the needs of the JIP.

The Data Collection Workshop began with a general session to familiarize the attendees with the NETL/DOE Gas Hydrates research program and the JIP plans for research into the properties of naturally occurring gas hydrates in the deepwater Gulf of Mexico. **Brad Tomer** (DOE/NETL) provided an overview of the DOE gas hydrates research program. To help attendees focus on what was needed from the workshop, **Emrys Jones** (ChevronTexaco) gave an overview of the JIP and its goals. **Mike Smith** (MMS) discussed current deepwater operations in the Gulf of Mexico and what is known about naturally occurring gas hydrates in the region.

Charles Paull (Monterey Bay Aquarium Research Institute) discussed his past experiences in obtaining deepwater core samples containing gas hydrates. **Bob Hardage** (Bureau of Economic Geology) discussed using 4-component (4C) ocean-bottom-cable seismic data to characterize seabed hydrate reservoirs and their mechanical properties. **Dendy Sloan** (Colorado School of Mines) provided an overview of what is known regarding the physical properties of gas hydrates and the importance of having accurate fundamental data to understand the phase behavior of naturally occurring hydrates. **Dick Plumb** (Schlumberger) discussed the subject of modeling for designing systems used when drilling and producing wells through zones that contain naturally occurring gas hydrate deposits.

These seven keynote presentations set the stage for an excellent workshop. Presentation materials from the general session are posted separately on the JIP website at the following address:

https://qpext.chevrontexaco.com/QuickPlace/wwuexpl_gashydrates/Main.nsf/h_4CE8EB048234FE2388256B5E0043A3EE/CEDF97717E17E4EE86256B8A0072AFF3/?OpenDocument

After the general session, the workshop was divided into three (3) breakout groups on the basis of the attendee's specialties and preferences. The three breakout groups were as follows:

- Group A – Pre-Drilling Hydrate Detection Methods
- Group B – Properties of Naturally Occurring Gas Hydrates
- Group C – Drilling in and Modeling of Naturally Occurring Gas Hydrates

Again, the purpose of these breakout groups was to identify the existing data and knowledge in the public domain that could be used by the JIP to accomplish its goals, and what gaps in data or technology need to be worked on by the JIP.

2.1.1 Breakout Session – Group A - Pre-Drilling Hydrate Detection Methods

Objective: The objective of Breakout Session Group A was to focus on determining the status of existing (i.e., seismic) and developing (i.e., geochemical analyses) technologies and available data for locating naturally occurring hydrates prior to drilling.

The group then compiled a list of items, data, and technologies needed to improve the ability of the scientific community to detect naturally occurring gas hydrates prior to drilling. The list is as follows:

- A data base with all existing information on the presence of gas hydrates in the deepwater Gulf of Mexico;
- Information that can be used to calibrate shear wave data to the presence of gas hydrates in the subsurface;
- More information on specific locations in the deepwater Gulf of Mexico where gas hydrates are known to exist;
- Access to existing 3-D seismic data in areas of interest;
- Access to OBC. (Ocean Bottom Cable) 4-C; de-tag data (deep towed), if it exists;
- Better seismic interpretation methods, i.e. a holistic approach that will show the presence of gas hydrate deposits; and
- Heat flow (3D) gradient mapping in the areas of interest.

2.1.2 Breakout Session – Group B - Properties of Naturally Occurring Gas Hydrates

Objectives: This session dealt with what is known and what needs to be known regarding hydrate properties and methods to sample and analyze naturally occurring gas hydrates.

Results: This group first developed lists of what we know and what we do not know about naturally occurring gas hydrates.

What we know about naturally occurring gas hydrates can be summarized as follows:

- Important properties involve kinetics, mechanical properties, sediment effects, and flow properties;
- Large variability exists in properties measured and reported in the literature. This variability may be due to experimental errors or lack of experimental standards;

- Standard sample fabrication methods are needed to assure repeatability; and
- We need a multidisciplinary approach to property characterization

What we need is summarized as follows:

- Better kinetic rate equations;
- Better measurements of all properties of naturally occurring hydrates in sediments, to include acoustic, thermal, mechanical, kinetics, electrical, logging, and microbial;
- Better flow characteristics of hydrates + sediments, to include permeability and capillary measurements;
- Better rock physics to explain how hydrates and sediments co-exist;
- Information on how hydrate properties vary with composition;
- Information on how well hydrates created in the laboratory accurately represent hydrates found in nature;
- Better rapid screening tool for QC of sample cores containing gas hydrates; and
- We need to establish a data base on existing Gulf of Mexico cores to define representative lab samples.

Attendees of breakout Session B were surveyed to provide their assessment of the importance of 11 different properties of hydrates in sediments to three different aspects of naturally occurring hydrates, namely 1) potential drilling/seafloor stability hazard, 2) detection of hydrates in the exploration phase, and 3) production of natural gas from hydrates as an energy resource. Results showed that:

- Kinetics of decomposition and mechanical properties were most important for estimating hazards;
- Seismic and geophysical properties were most important for exploration; and

- Kinetics of decomposition along with permeability/flow properties and hydrate saturation in sediment were most important for production of hydrates.

2.1.3 Breakout Session – Group C - Pre-Drilling Hydrate Detection Methods Drilling in and Modeling of Naturally Occurring Gas Hydrates

This session focused on the different models needed for safe drilling and operation in sediments containing gas hydrates. It looked at case histories and past experience with drilling and coring hydrates.

The following represent lessons learned that became evident as the attendees discussed various case histories.

- Capturing undisturbed samples of gas hydrates under field conditions has been difficult to accomplish.
- Smaller diameter core did not work on the first Mallik well.
- Chilled drilling mud is of assistance in preserving the cores.
- Use of a "Kinetic Modifier" (a mud modifier, Lecithin) and lower mud weights (10.5 ppg warm mud) significantly reduced hydrate problems in North Slope drilling of conventional oil wells.
- There is a need to understand the kinetics associated with mud columns.

In the brainstorming part of breakout Session C, three issues were discussed: 1) what laboratory scale tests are required to validate models?, 2) what are the current protocols for taking and handling core samples?, and 3) what data are required and what modeling needs to be done in order to select sites for drilling in Phase II of the JIP?

The most important results from the brainstorming session were as follows:

- Laboratory scale tests are needed to collect data on all thermal properties (conductivity, heat capacity, etc.);

- Data are also needed on dissociation kinetics with and without drilling mud, and on acoustic, mechanical, elastic, and physical properties of hydrates in sediments;
- Coring protocols used currently include keeping the core in original temperature and pressure conditions, using a safe method for transfer, transport, and storage of pressurized core barrels, re-entering the borehole with logs to test hole stability, and sampling away from the borehole; and
- Data/modeling required to select drill sites must include completing a geophysical model to quantify hydrate volumes and other overall properties, completing geological characterization to create a clear model for testing, and integrating scientific and industry objectives.

2.2 Drilling, Coring and Core Analysis Workshop

This workshop focused on the current state-of-the-art with respect to planning for taking cores, safety issues, core sampling and preservation and core analysis. The objective of this workshop was to determine what is currently known regarding coring in hydrates and what major gaps in technology need to be filled. Three breakout sessions were conducted as part of this workshop as follows:

- Session D1 - Drilling and Coring Well Plan and Safety Issues
- Session D2 - Core Sampling and Core Preservation
- Session D3 – Core Analysis

2.2.1 Detailed Results - Group D1 - Drilling and Coring Well Plan and Safety Issues

This session focused on drilling, coring and logging mechanical and safety issues, to include the following:

- Hydrate specific safety issues;
- Components of the well plan;
- Requirements for a usable bore hole;

- Drilling fluid design to include inhibitors and temperature;
- Coring tools to include barrels and bits;
- ROV for observation and or sampling; and
- Wireline logging, logging while drilling (LWD) and, Vertical Seismic Profiling (VSP).

This session focused on drilling, coring and logging mechanical and safety issues as it relates to hydrates. Specific issues included key components of the well plan, requirements for a usable wellbore and drilling fluid design. In addition coring and logging tools were addressed along with the role of ROVs.

Key conclusions of this workshop were:

- Regarding well planning, key issues were identified as risk analysis, the need to determine temperature throughout the circulating systems and the need for a flow chart for core analysis. In addition several sources of past well plans and related references were identified.
- Weighted and chilled drilling fluids were identified as key factors in minimizing hydrate dissociation. Freshwater was considered bad for shale stability and it was felt that hydrate dissociation inhibitors could probably improve upon Lecithin.
- Several sources of hydrate related safety plans were identified.
- Several sources of coring tools and their uses were identified. These are primarily wire-line retrieval systems that may require special drill strings, but that also provide a lot of options.
- It was concluded that the use of an ROV during drilling and/or coring was not needed or worth the money. It was unknown whether the MMS would have this as a requirement however.

2.2.2 Detailed Results - Group D2 Core Sampling and Core Preservation

This session focused on the challenges of safely preserving hydrate bearing cores in their original downhole condition and sampling them for lab analysis. Specific topics included pressure and temperature maintenance, shipping, safety, transportation and on-site sampling.

Key conclusions of this workshop were:

- To design core sampling and core presentation work plans, the JIP must develop a flow chart that clearly enumerates what measurements will be needed, where, when and by what process they will be obtained.
- Only after knowing exactly how much core is needed, where the core is needed and for what purposes the core will be used can the JIP come up with a realistic plan to preserve and transport that core.
- Several gas hydrate coring projects, Mallik 2L-38, ODP Leg 204 and Anadarko's Arctic Project, have just been completed or will be conducted soon. The JIP should watch these projects very closely and apply all best practices.
- Preserving core temperature is critical. There was some concern identified, however, over the use of liquid nitrogen to accomplish this due to the potential of the nitrogen to change the hydrate properties due to molecular interaction.
- Transportation of pressurized core samples should be by land or sea and not by air.
- Once the core is taken, there was a high degree of interest in instrumenting the hole and surrounding seafloor and gathering additional data over time. This should help integrate the core data and provide information on the dynamics of hydrate sediments.

2.2.3 Detailed Results - Group D3 Core Analysis

This workshop focused on what type of core analysis and lab testing should be performed on cores gathered in Phase II of the JIP, and what are the relative priorities for the testing. This included on-site core analysis and analysis of the cores while under pressure and in the lab. Properties to be considered included mechanical, geochemical, physical and electrical.

Key conclusions of this workshop were:

- Three primary reasons for the need of accurate core analysis were identified. These were the need to 1) assess hydrate impact on wellbore stability, 2) assess hydrate impact on pipeline stability and 3) to calibrate remote sensing data (e.g. seismic).
- The state-of-the-art for coring is currently defined by the Mallik wells and ODP Legs 201 & 204.
- The primary gaps in coring are 1) obtaining representative natural cores, 2) synthesizing representative laboratory cores and 3) gaps in testing protocols.
- A list of important mechanical properties needed from core analysis was developed. This included stress strain curves, moduli, resistivity, porosity, permeability, hysteretic phenomena and compaction properties.

A **common theme** emerged. It was clear that there is a significant opportunity for the JIP to improve the state of knowledge of naturally occurring gas hydrates, by gathering in-situ seafloor and/or wellbore data, via downhole instrumentation, over time. There is an almost total lack of in-situ data taken over an extended period of time. The use of instrumentation on the seafloor and/or in wellbores could provide valuable insight into the stability of hydrates over time, and a better understanding of the process of dissociation.

2.3 Modeling, Measurements and Sensor Workshop

The workshop on modeling, measurements and sensors focused on the current state-of-the-art with respect to the stability of hydrate sediments, data required to improve modeling, the impact of local seafloor instabilities and the use and role of seismic and reservoir modeling to improve our understanding of hydrates. The objective of the workshop was to determine what is currently known in these areas and what the major gaps or unknowns are. Three breakout sessions were conducted as part of this workshop as follows:

- Session M1 – Wellbore Stability
- Session M2 – Modeling Seafloor Instability

- Session M3 – Seismic Attributes and Verification of Seismic Analysis

Prior to starting the breakout sessions, a series of overview presentations were made.

10:00 am	"Predictive Numerical and Effective Media Models of Gas Hydrate-Bearing Sediments" by Carolyn Ruppel, Georgia Tech
10:30 am	"Kinetic Models of Hydrocarbon Gas Generation and Venting" by Larry Cathles, Cornell University
11:00 am	"Sensors and Measurements" by Bob Kleinberg, Schlumberger

These three presentations can be found on the JIP website.

2.3.1 Breakout Session M-1 on Wellbore Stability

This breakout session addressed stability of hydrate bearing sediments as it relates to wellbores. Specifically, it addressed what is known about current wellbore stability models, what field data is needed to improve these models and what tests could be run in the Phase II test wells to improve our wellbore stability concepts and models.

Key conclusions of this workshop were as follows:

- A comprehensive list of known physical properties of hydrates, as it pertains to wellbore stability were identified;
- Five high priority areas, where additional data on the properties of hydrates is needed were identified. These related to

  1) Kinetics of hydrate dissociation,

  2) Acoustic properties,

  3) Distribution of hydrates in pores,

  4) Mechanical properties, and

  5) Heat flow data;

- Relating the data from above to wellbore stability predictions or modeling is a key challenge;
- Several data sources were identified regarding past or ongoing studies with respect to wellbore stability; and
- A valid model for wellbore stability does not appear to exist at this time and there was not agreement on whether one was needed or possible to develop in the JIP's timeframe.

This session considered the stability of hydrate bearing sediments, the data required to improve modeling, and what can usefully be collected from the test wells. It was also concerned with

- What is known about the physical properties of these sediments,
- Who has the data,
- What is known about the current models and their ability to handle unconsolidated hydrate bearing marine sediments,
- What features need to be added,
- Hydrate dissociation modeling issues,
- Equations for describing low strength soils,
- What field data are needed to validate the models,
- What lab work can supplement the development/validation of the models,
- What tests can be run in the test wells drilled in the 2nd phase of this JIP before final abandonment to check wellbore stability concepts.

2.3.2 Breakout Session M-2 on Modeling Seafloor Instability

This breakout session addressed seafloor instabilities, due to hydrates, on both a local and a large-scale basis. Items to be addressed were the ability of current models to predict hydrate presence and properties over time, the status of existing models, case histories of local instabilities and items to consider in selecting drill sites for Phase II of the JIP.

Key conclusions of this breakout session were as follows:

- There are few documented case histories of local seafloor instabilities.
- We know how to avoid areas of obvious hydrate concentrations that can be readily identified by faulting, mounds and vents.
- We know how to identify areas with a high probability of having no hydrates in the sediment, due to either no sources of gas and/or the physical features in the area.
- One big challenge is to predict the impact of disseminated hydrates that exist in low concentrations, in areas that currently "appear to be safe."
- There was consensus that in Phase II, the JIP should drill three test holes, in the same geologic area, to test locations of low, disseminated and high hydrate concentrations. (Several specific potential sites were identified).
- Large-scale instabilities, due to hydrates, in the Gulf of Mexico are not a clearly proven phenomenon, and the attention of the JIP at this time should focus on "local" instabilities.

This breakout session focused on potential large-scale seafloor instabilities, and instabilities local to production facilities due to natural gas hydrates in the subsea sediments. Session topics included:

- Discussion of case histories of known local instabilities believed to be caused by dissociation of gas hydrates in subsea sediment;
- Determine current status of models, understanding of trigger mechanisms;
- Define data needed to constrain existing models and to develop improved models;
- Determine basis for selecting drill site in Phase 2 to provide the needed data;

- Define procedures for obtaining the needed data from cores and in-situ tests in Phase 2; and
- Discussion of case histories of large-scale seafloor instabilities.

The overriding purpose of this breakout session was as follows:

- Determine the state of current models and the case histories regarding seafloor instabilities;
- Develop ideas and plans as to how to move forward in the JIP's Phase II (approximately three wells currently planned); and
- Make connections with individuals/companies that may have proposals or specific plans on how to execute Phase II.

The breakout session participants next listed some of the gaps in knowledge affecting seafloor stability modeling. These gaps are as follows:

- Mechanical/Thermal prediction capabilities are missing in many of our models;
- Current Seismic Surveys do not give us the capability to accurately predict hydrate content;
- Seismic surveys need to be calibrated against models to verify hydrate content and properties;
- Ability to predict the location of hydrates is rather primitive;
- Most models assume homogeneity;
- Seismic, thermal, and electrical models are not very sophisticated; and
- Our ability to predict the concentration of disseminated hydrates is very poor.

2.3.3 Breakout Session M-3 on Seismic Attributes and Verification of Seismic Analysis

This breakout session addressed the role of seismic data in geoscience and reservoir modeling to better predict the characteristics of hydrate bearing sediments. Specific areas of focus included acquisition and processing requirements for seismic data, prioritization of seismic data requirements and procedures to allow calibration of seismic data to cores collected in Phase II of the JIP.

Key conclusions of this breakout session were as follows:

- Rock properties modeling and its impact on seismic acquisition and processing were identified as a major unknown regarding the ability of seismic to define the characteristics of hydrate sediments.

- Several model based processing issues and the role of multi-component data were identified as major unknowns for seismic acquisition and processing required to model hydrates and their distribution.

- Three major unknowns were identified regarding seismic data requirements to develop geoscience and reservoir models. These were 1) how to extract rock properties from seismic data, 2) how to tie seismic data to the geologic model and 3) how to marry rock properties with reservoir properties. Several potential approaches were identified to close these gaps.

- Selecting a proper drill site, in a high hydrate concentration area, will be critical to enhance the calibration of seismic data to new core data. Key unknowns are a list of criteria to select a proper drill site. Several potential approaches to developing those criteria were identified.

3.0 DATA COLLECTION WORKSHOP

The ChevronTexaco Gulf of Mexico Gas Hydrates JIP, in collaboration with NETL/DOE, is investigating naturally occurring gas hydrates in the Gulf of Mexico. The goals of the JIP include:

- Developing technology to assist in characterization of deepwater, naturally occurring gas hydrates in the Gulf of Mexico;
- Understanding how natural gas hydrates affect seafloor stability;
- Gathering data to aid climate change studies; and
- Determining how project results can be used to assess if and how gas hydrates act as trapping mechanisms for shallow oil or gas reservoirs.

Phase 1 of this multiphase, multiyear project includes data collection, analysis and model development. Research results will be compiled in a data base and the results will be used to plan the drilling, measurement, and sampling program conducted in Phase II.

A website has been developed to house the data and information that were collected in the Data Collection Workshop, as well as other items submitted during the course of this research endeavor. The link to the JIP website is as follows:

http://qpext.chevrontexaco.com/QuickPlace/wwuexpl_gashydrates/Main.nsf?OpenDatabase.

The website is divided into a public site and a site reserved for JIP Member Companies. The detailed reports from the Workshops conducted by the JIP can be found in the Library portion of the website that is open to the public.

The first workshop was the Data Collection Workshop that was held in Houston March 14-15, 2002. The purpose of this workshop was to find out what data concerning natural gas hydrate deposits in the deepwater portion of the Gulf of Mexico was in the public domain and could be used by the JIP. The workshop also tried to identify data that would be available for use by the JIP that was not necessarily in the public domain.

The second and third workshops were held simultaneously in Houston on May 9-10, 2002. The Modeling, Measurements and Sensors Workshop was designed to find out exactly what the various engineering and geoscience modelers wanted from the JIP field data collection effort. The Drilling, Coring and Core Analysis Workshop was designed to begin the process of determining how the JIP can go about collecting the data that the modelers and scientists desire.

Thus, the three workshops were designed to (1) inventory the data currently available on naturally occurring gas hydrates in the deepwater Gulf of Mexico, (2) determine what additional data need to be collected for the modelers and scientists, and (3) determine how to collect the data.

In general, these workshops were very successful and met the expectations of the JIP members who planned and conducted the workshops. Attendance was high at both workshops – 93 attendees in March and 81 attendees in May. Feedback from the attendees was positive and the research project has benefited greatly from the information exchanged at the two workshops. Details concerning the workshops are presented in the Appendices of this report and on the JIP website.

The Data Collection Workshop was held to determine what data are available concerning natural gas hydrate deposits in the deepwater Gulf of Mexico. The specific goals of the Data Collection Workshop were as follows:

- To develop an understanding of the safety issues involved in drilling and operating in marine sediments containing naturally occurring hydrates through case histories;
- To determine what is known and what needs to be known for accurate detection and seismic interpretation of hydrate bearing sediment zones using seismic, geochemical, well logging, well testing and drilling data;
- To determine what is known and what needs to be known about the physical, thermo-chemical, and biogeochemical properties of hydrate bearing sediments to accurately evaluate and model sediment stability;
- To assimilate data on naturally occurring hydrates in the Gulf of Mexico;

- To gather all data in the literature, as well as from public and private sources that pertain to naturally occurring hydrates in deepwater Gulf of Mexico;
- To develop a preliminary format and content for a data base to be used by the JIP to store collected data and to select drilling sites in Phase II of the project; and
- To identify individuals and institutions that can assist in obtaining the necessary data and technology to meet the needs of the JIP.

A summary of the Agenda for the workshop is given below:

Thursday, March 14th, 2002

8:10	NETL/DOE AND JIP OVERVIEW DOE Hydrate Projects Overview, Brad Tomer JIP Overview and Review of Workshop Goals, Emrys Jones
9:00	NATURALLY OCCURRING GAS HYDRATES REGIONAL OPERATING EXPERIENCES Gulf of Mexico Operations, Michael Smith Operations Around the World, Charles Paull
10:15	WHAT WE KNOW AND WHAT WE NEED TO KNOW TO OPERATE SAFELY IN REGIONS CONTAINING NATURALLY OCCURRING GAS HYDRATES Technology for Detecting Naturally Occurring Hydrates, Bob A. Hardage Properties of Naturally Occurring Gas Hydrates, Dendy Sloan, Jr. Modeling for Designing Systems in Zones Containing Naturally Occurring Gas Hydrates, Dick Plumb
1:00	BREAKOUT SESSIONS Session A – Pre-Drilling Hydrate Detection Methods Session B – Properties of Naturally Occurring Gas Hydrates Session C – Drilling in and Modeling of Naturally Occurring Gas Hydrates
5:30	POSTER SESSION RECEPTION

Friday, March 15th, 2002

8:00	RECAP AND REFOCUS ON BREAKOUT SESSIONS, Emrys Jones
8:30	Breakout Session A: Continuation and wrap-up Breakout Session B: Continuation and wrap-up Breakout Session C: Continuation and wrap-up
10:30	BREAKOUT SESSION REPORTS
11:45	CLOSING COMMENTS, Emrys Jones

3.1 General Session

The Data Collection Workshop began with a general session to familiarize the attendees with the NETL/DOE Gas Hydrates research program and the JIP plans for research into the properties of naturally occurring gas hydrates in the deepwater Gulf of Mexico. Presentations were also made to discuss operations in oceans where natural gas hydrates exist, and what we need to know to operate safely in regions containing natural gas hydrates.

Brad Tomer (DOE/NETL) provided an overview of the DOE gas hydrates research program. Tomer said that funding for the program in 2003 is uncertain, but he anticipates that Congress will continue its strong support. He reviewed studies covering the DOE work on hydrate occurrence, remote sensing, deep-tow acoustic resolution, improved resolution testing (to take place this summer), sampling and in-situ measurement were covered in some detail. Tomer stated that Maurer and Anadarko, as well as BP and the Mallick project will be conducting DOE sponsored research to further investigate how to produce natural gas associated with gas hydrate deposits. When asked the question, "What is the definition of the program?", Tomer answered "To answer basic questions concerning hydrates and to determine if hydrates are a viable resource."

To help attendees focus on what was needed from the workshop, **Emrys Jones** (ChevronTexaco) gave an overview of the JIP and its goals. Emrys explained the JIP business issues, the scientific goals of the JIP, and what the JIP hoped to accomplish during the workshop. Jones stated that the materials generated as a result of this workshop will be published and available to each attendee. The workshop goals are to define what we know and what we do not know. In addition, we need to determine how to relate scientific data to engineering information. An example of the challenge in the thermal physical and mechanical property area is how to relate synthetic core data to sediment cores. In the drilling and casing area, a challenge is how to obtain high quality log and core data safely.

Mike Smith (MMS) discussed current deepwater operations in the Gulf of Mexico and what is known about naturally occurring gas hydrates in the region. Dr. Smith's presentation included a series of informational slides covering Gulf of Mexico operations and operating experiences related specifically to naturally occurring gas hydrates in the Gulf of Mexico. He defined deepwater as being greater than 1500 ft., and stated that there are currently 2000 active leases in the Gulf of Mexico. Gulf of Mexico deepwater exploration includes some 625 wells in greater than 1440 ft. water depth with 33 currently drilling in mid-deepwater. Smith stated that Gulf of Mexico hydrates occur as hydrate mounds and usually seen as active gas vents. He commented that seafloor hydrates are not static and can be a hazard to pipelines and structures. It was noted that the majority of the 625 wells drilled in deepwater have not come close to hydrate areas. Smith also discussed the collaborative effort between MMS and the JIP that will be used to select drilling sites.

Charles Paull (Monterey Bay Aquarium Research Institute) discussed his past experiences in obtaining deepwater core samples containing gas hydrates. Paull stated that little work has been done on gas hydrates worldwide, with the majority of work coming from the Ocean Drilling Program (ODP). Specifically, he discussed the ODP Leg 164 experience on the Blake Ridge. Paull noted the difficulty they experienced in obtaining quantitative hydrate compositions, and how they resorted to indirect methods to determine hydrate concentrations. He also discussed his experience with using pressurized core samplers. His conclusions were as follows: 1) There have been few attempts to drill for gas hydrates; 2) Gas hydrates are difficult to detect in bore holes; and 3) It may be difficult to predict production based on pre-measurements.

Bob Hardage (Bureau of Economic Geology) discussed using 4-component (4C) ocean-bottom-cable seismic data to characterize seabed hydrate reservoirs and their mechanical properties. The sensor package used to acquire 4-C marine data consists of a 3-C geophone and a hydrophone. Hardage discussed the advantages of using 4-C seismic data and noted the major drawback in its use is higher cost than conventional 3-C seismic surveys. The key point stressed in the presentation was that an integrated interpretation of the P-wave and SV images obtained from 4-C data yields more information about the stratigraphy and structure of gas-hydrate systems than does the interpretation of conventional hydrophone P-wave data. The advantage of 4-C data in evaluating gas-hydrate systems is that each wavefield (P and SV) often images a different suite of stratal surfaces than does the other wavefield. Both images are correct, but one image provides information about the depositional system that does not exist, or is difficult to decipher, in the other image.

Dendy Sloan (Colorado School of Mines) provided an overview of what is known regarding the physical properties of gas hydrates and the importance of having accurate fundamental data to understand the phase behavior of naturally occurring hydrates. Sloan then discussed the mechanical similarities of hydrates to ice, noting that they were very similar, except in thermal and strength properties. A list was presented for tools used in hydrate measurement, such as the non-destructive spectrographic methods of diffraction, NMR, and Raman spectroscopy. Dendy noted that Raman spectroscopy looks very good for in-situ hydrate detection in the future, and that Monterey Bay Aquarium Research Institute has already outfitted a Remotely Operated Vehicle (ROV) with a Raman probe on a mechanical arm, with spectra transmitted to shipboard. He suggested that needs for future work be directed toward measuring hydrates in place and obtaining samples from the ocean floor.

Dick Plumb (Schlumberger) discussed the subject of modeling for designing systems used when drilling and producing wells through zones that contain naturally occurring gas hydrate deposits. Plumb outlined the steps required in the drilling, planning, and execution process for drilling wells in zones containing hydrates. He noted that the a mechanical earth model could take up to six months to prepare, which could be too long of a time frame for most operations. Plumb concluded with a list of "what's needed to conduct successful modeling" that included the following: 1) excellent formation characterization; 2) the mineralogy (grain size, porosity, etc.) of the various layers; 3) the development of better models; 4) characterization of the state of stress as a function of depth; 5) characterization of mechanical properties of the various layers that will be penetrated; and 6) development of methods for enabling key environmental parameters.

These seven keynote presentations set the stage for an excellent workshop. Presentation materials from the general session are posted separately on the JIP website at the following address:

https://qpext.chevrontexaco.com/QuickPlace/wwuexpl_gashydrates/Main.nsf/h_4CE8EB048234 FE2388256B5E0043A3EE/CEDF97717E17E4EE86256B8A0072AFF3/?OpenDocument

After the general session, the workshop was divided into three (3) breakout groups on the basis of the attendee's specialties and preferences. The three breakout groups were as follows:

- Group A – Pre-Drilling Hydrate Detection Methods
- Group B – Properties of Naturally Occurring Gas Hydrates
- Group C – Drilling in and Modeling of Naturally Occurring Gas Hydrates

Again, the purpose of these breakout groups was to identify the existing data and knowledge in the public domain that could be used by the JIP to accomplish its goals, and what gaps in data or technology need to be worked on by the JIP.

3.2 Breakout Session – Group A - Pre-Drilling Hydrate Detection Methods

Objective: The objective of Breakout Session Group A was to focus on determining the status of existing (i.e., seismic) and developing (i.e., geochemical analyses) technologies and available data for locating naturally occurring hydrates prior to drilling.

Results: The group first determined what indicators could be used to detect the presence of naturally occurring gas hydrates in deepwater. The indicators identified were as follows:

- Heat flow gradient;
- Bubbles/seep detection and observation; and
- Geochemical analysis (but need cores/core data).

The group then compiled a list of items, data, and technologies needed to improve the ability of the scientific community to detect naturally occurring gas hydrates prior to drilling. The list is as follows:

- A data base with all existing information on the presence of gas hydrates in the deepwater Gulf of Mexico;
- Information that can be used to calibrate shear wave data to the presence of gas hydrates in the subsurface;

- More information on specific locations in the deepwater Gulf of Mexico where gas hydrates are known to exist;
- Access to existing 3-D seismic data in areas of interest;
- Access to OBC (Ocean Bottom Cable) 4-C; de-tag data (deep towed), if it exists;
- Better seismic interpretation methods, i.e. a holistic approach that will show the presence of gas hydrate deposits; and
- Heat flow (3D) gradient mapping in the areas of interest.

The discussion pointed out that various groups will have various motives when looking for naturally occurring gas hydrates in deepwater. Some companies may be looking to find gas hydrates to determine if natural gas can be produced from the hydrates or from free gas trapped by the gas hydrate deposits. Other companies may be trying to avoid gas hydrates so as not to jeopardize the development of deeper oil and gas deposits. Depending on the goals of the various groups, the various technologies listed in the following table may or may not be sufficient.

Comments Concerning the Adequacy of Various Technologies Used to Find Naturally Occurring Gas Hydrates

Method	Want to Find Hydrates*	Prove Conclusively – Do Not Want to Find Hydrates**
Streamer Seismic	OK	Not good enough
OBC (Ocean Bottom Cable)	Overkill	Necessary and critical
Core	Yes	Necessary
Petrophysics	Useful	Critical
Rock properties	OK	Critical
De-tags and alternatives	Important	Less important
Shallow hazards	Yes	Critical (government required)

*Want Hydrates - an explorer looking to commercially produce hydrates

**Prove Conclusively – No Hydrates – Conventional offshore operations trying to avoid hydrates from a safety and environmental perspective

Discussion: The first item addressed by Breakout Group A was to identify the quality and quantity of seismic data that would be available to the JIP. It was determined that regional and site specific, conventional and possibly some high-resolution data are available; however, processing workflows and vintages of the data vary widely. It was mentioned that seismic data from over 63 different sites including the Joliet Field (GC 184/185),), the Mars/Ursa region (MC 852/853) (very large) and Atwater Valley 425 are available to everyone.

In the course of the discussion, it was pointed out that the first gas hydrates found were at Joliett Field. The known gas hydrate deposits extend from the Western Gulf of Mexico to the Eastern Gulf of Mexico. Hydrates typically occur 400-500 meters below the seafloor. Hydrate zones may be 500 meters thick and at MC 852/853, the zone may be even thicker. MC 852/853 and GC 184/185 are generally regarded as methane gas hydrate elephants. These three areas each contain 6 or 7 vertically stacked gas hydrate zones. Geochemical data are available, as well as samples and descriptions of the hydrates.

One participant suggested that there are a significant number of 3D seismic data sets that essentially cover the Gulf of Mexico, including deepwater. There are 1,000 km of 2-D lines, full-scale plots and multi-fold geo-hazard data available from the USGS. In the Joliet Field/Bush Hill site, we have hazard surveys with data from submersible vessels. The Joliet/Bush Hill site is good candidate to study gas hydrates in-situ. Conoco has proposed that the Joliet Field 3D surveys be provided to the JIP data base, with the charges to the JIP being tape reproduction charges and licensing fees.

Fugro has data from various clients that could potentially be added to the JIP data base, pending client permission. BEG is involved in a DOE funded gas hydrates study. Pending approval from the participants in the study, the data will be posted on the DOE website, and will then be accessible to all. After two years, all offshore subsurface data such as well logs, core data, etc., goes into the public domain. Seismic data becomes public only after twenty-five years.

It was mentioned that the JIP must consider whether the drilling program will be in fine-grained sediments or a courser grained sediment. Significant hydrate accumulations are found in the coarser grained sediments. The relationship between these sediments as well as hydrates and shales needs to be further studied. Geophysical calibration with the geologic environment needs to be done to aid in understanding the complex relationships between hydrates and the surrounding rock.

It was recommended that the JIP should consider taking piston cores to ascertain the suitability (e.g. water depth, temperature, etc.) of any given location for hydrates before starting any other type of acquisition. The Group then prepared a list of possible alternative measurement techniques to better quantify the presence of naturally occurring gas hydrates. The list is as follows:

- Resistivity measurements;
- Magnetic radiometry;
- Methane sniffers;
- Piston cores;
- Side-scan sonar;
- Seafloor compliance;

- Spectroscopic process;
- Seafloor electrical measurements;
- Isotopic portable mass spectroscopy units;
- Analyze while drilling/real time data; and
- High Resolution Magnetic Radiometry.

In Columbia and Peru, microseismic tomography has been used to image shallow formations. Approximately 100,000 km of data have been acquired. In this procedure, a fixed array of seismic sensors is placed over the area of interest, and the data are recorded, down to a magnitude of –1. This technique allows for an infinite number of source positions and gives both full S and P waves. In Columbia and Peru this has led to faults being imaged which more conventional seismic blew through. Traditional seismic images the larger events, but with microseismicity, it is possible to extrapolate into the small events, yielding data, which are below the resolution of conventional seismic (magnitude vs. occurrence). To date, this technique has been used onshore only, but it will be used at Sakhalin this summer. The NRL is also designing tests for an ocean bottom source for the deepwater Gulf of Mexico.

Group A next discussed what changes in seismic interpretation and processing are required to more reliably detect naturally occurring gas hydrates. The rarity of BSRs in the Gulf of Mexico, particularly in the northern Gulf, does not mean that there are no hydrates present. Even if there is a BSR present, there is no guarantee that hydrates exist in that location. Indications are that BSRs are not necessarily related to hydrates, and there is some evidence that temperature variations and salt may lead to the formation of a BSR without hydrates. Even if the proper stability zone for hydrates exists in a given location, a BSR may not be visible. Instead of concentrating on looking for BSRs, we need to look for other changes from seismic records that might signal hydrates. For example, strong amplitudes that seem to terminate for no apparent reason may indicate the presence of gas hydrates. These lateral changes warrant study as they may also provide indications of hydrates.

There is a great need to have multicomponent data available to use for hydrate detection. It is essential to have the S wave data as well as the P wave data. Shear data sees what the lithology really is, unlike P wave data. Combining both P and S wave data leads to better reservoir and sequence stratigraphy interpretations.

Recommendations in Processing Seismic Data for Detecting Gas Hydrates were as follows:

- No muting of data should be allowed;
- Relative amplitude should be preserved;
- Processing procedures should be used to eliminate multiples to prevent confusion with possible BSRs;
- Waveform inversion should be used to extract elastic properties;
- We should maintain processing fidelity to reduce/eliminate distortion of data;
- We should exercise caution in filtering, stacking, and migrating data – hydrate features may be much smaller than in conventional plays, and we need to be looking for detailed features; and
- Attention needs to be focused on getting the Vp/Vs ratio correct for shallow data when OBC data is processed.

In a general discussion, the following comments were important. We need to take the geothermal gradient, and pressure gradient into consideration when evaluating zones for gas hydrates. Don't be limited into only looking for BSRs because lateral changes and variations in seismic character may be the key to hydrate detection in many situations. Don't let the geophysical model necessarily be the lead in looking for hydrates.

It was also pointed out that in the deepwater regions of the Gulf of Mexico, the salt exists in a very dynamic environment. As the salt moves around and sediments become faulted, gas and fluids travel up the faults in both vertical and lateral directions. Once the gas moves into a region where the geothermal/pressure gradients are conducive to hydrate formation, hydrates will form.

In summary, the detection of gas hydrates is very difficult in the Gulf of Mexico. There is little likelihood of encountering a BSR in the Gulf of Mexico (with standard acquisition methods), and even if there is a BSR, it may not necessarily have anything to do with gas hydrates. However, if a BSR is present, chances are high that it will have at least a small amount of hydrates associated with it. As such, a holistic rather than just a geophysical approach must be taken in the way in which gas hydrate locations are inferred, interpreted, and located.

3.3 Breakout Session – Group B - Properties of Naturally Occurring Gas Hydrates

Objectives: This session dealt with what is known and what needs to be known regarding hydrate properties and methods to sample and analyze naturally occurring gas hydrates.

Results: This group first developed lists of what we know and what we do not know about naturally occurring gas hydrates.

What we know about naturally occurring gas hydrates can be summarized as follows:

- Important properties involve kinetics, mechanical properties, sediment effects, and flow properties;
- Large variability exists in properties measured and reported in the literature. This variability may be due to experimental errors or lack of experimental standards;
- Standard sample fabrication methods are needed to assure repeatability; and
- We need a multidisciplinary approach to property characterization

What we need is summarized as follows:

- Better kinetic rate equations;
- Better measurements of all properties of naturally occurring hydrates in sediments, to include acoustic, thermal, mechanical, kinetics, electrical, logging, and microbial;
- Better flow characteristics of hydrates + sediments, to include permeability and capillary measurements;

- Better rock physics to explain how hydrates and sediments co-exist;
- Information on how hydrate properties vary with composition;
- Information on how well hydrates created in the laboratory accurately represent hydrates found in nature;
- Better rapid screening tool for QC of sample cores containing gas hydrates; and
- We need to establish a data base on existing Gulf of Mexico cores to define representative lab samples.

Attendees of breakout Session B were surveyed to provide their assessment of the importance of 11 different properties of hydrates in sediments to three different aspects of naturally occurring hydrates, namely 1) potential drilling/seafloor stability hazard, 2) detection of hydrates in the exploration phase, and 3) production of natural gas from hydrates as an energy resource. Results showed that:

- Kinetics of decomposition and mechanical properties were most important for estimating hazards;
- Seismic and geophysical properties were most important for exploration; and
- Kinetics of decomposition along with permeability/flow properties and hydrate saturation in sediment were most important for production of hydrates.

In all cases, the respondents felt that less than 50% of the needed data was actually available, and most of the properties identified would need to be worked on for three to five years to advance our understanding of them.

The USGS reported on experimental results on natural gas hydrates. The USGS found that heat transfer modeling is critical to understanding the behavior of gas hydrates. USGS has measured thermal conductivity and thermal diffusivity of pure methane hydrate. There is not much high quality data available in literature. Their thermal conductivity measurements suggest that literature data can have a factor of 2 spread. Thermal conductivity is important for wellbore stability.

The USGS has also looked at preservation of hydrate cores and kinetics of hydrate decomposition. There is no satisfactory model/theory for kinetics of decomposition. The USGS data suggest some anomalous self-preservation phenomena just below the ice point. Their studies indicate that decomposition kinetics is path dependent. There is speculation that the anomalous phenomena during decomposition is due to the presence of ice. Dissociation rates of synthetic laboratory cores are very sensitive to temperature. Lowering temperature by just a few degrees affects rate of dissociation considerably. In the Mallik 2002 program, the mud was chilled to 2°C, and they obtained extraordinary recovery during this time due to chilling compared to no chilling.

The USGS has also looked at elastic wave speeds through compacted hydrate samples. Highly sensitive P and S wave speed data through compacted hydrate samples for both SI and SII hydrates have been obtained. As a next step, it is important (but difficult) to develop a rock physics theory for hydrate + sediment mixtures. For example, "How do Vp/Vs data relate to rock physics of hydrates in sediments?" The answer will depend on whether hydrates act as cement or if they structurally support the sediments or if they are in the pore space. Some laboratories can make reproducible pure methane hydrate samples for thermal/physical property measurements. The question that remains however, is "How representative is a lab hydrate sample to that found in nature?"

Ductile strength measurements, where one monitors stress vs. strain, suggest that gas hydrate is 20 times stronger than ice. Strength wise, the difference between gas hydrates and ice is comparable to the difference between stainless steel and hydrates. It has been hypothesized that the self-diffusion coefficient of water in hydrates, which is 100 times lower than that in ice, may be responsible for the unusually high strength of hydrates.

Many properties are required by a modeler of gas hydrates. One participant suggested that there are 9 critical areas/knowledge gaps that need to be worked on from a general modeling perspective for naturally occurring hydrates. These nine areas are as follows:

1. Is the dissociation process in the real world controlled by kinetics or equilibrium?

2. If kinetics is the controlling process, we need parameters for hydrate dissociation in consolidated and unconsolidated sediments that simulate field conditions.

3. How is the hysteresis behavior (observed between cooling and heating loops in a lab experiment) due to metastability relevant to modeling hydrates in sediments?

4. We need to know CH_4 solubility/dissolution near the hydrate point. In general, solubility of methane in water in equilibrium with hydrates is important, and very little data on gas solubility in water in the hydrate range are available.

5. We need relative permeability and capillary pressure measurements of cores that contain various saturations of gas hydrate.

6. We need acoustic, electrical, and thermal properties of hydrates in sediments over a large temperature range. How do these properties change for consolidated versus unconsolidated sediments?

7. We need a better description of anomalous kinetic/thermal self-preservation of hydrates sometimes observed during dissociation.

8. How do hydrate properties/phase behavior change as a function of hydrate stoichiometry, composition and hydration number? Can we measure hydration # better?

9. We need to know the mixing properties of hydrates in sediments, i.e. what mixing rules should we use when estimating properties of hydrate + sediment mixtures given properties of pure hydrates and pure sediments? We also need better rock physics models.

It was further stated that we specifically need solubility of gas in seawater in pore space, as opposed to bulk phase in the presence and absence of hydrates and as a function of salinity.

Concerning specific projects, several attendees described their experiences. Anadarko and Maurer Engineering have developed a portable laboratory for the analyses of cores and cuttings onsite. This laboratory is currently in the Arctic and may be available for appropriate programs. Anadarko and Maurer Engineering also have a DOE funded project looking at naturally occurring gas hydrates on the North Slope in the permafrost. They are looking for information on what sort of logs are needed for that project and welcome any suggestions.

Japan National Oil Corporation (JNOC) stated that wireline logging has provided significant information in their work on hydrates in the Nankai Trough. JNOC has a petrophysical model of the hydrate-bearing reservoir in the Nankai Trough: cement, sand, silt, dry clay, bound water, free water, and gas hydrate are considered in this model. During the Nankai work, they collected gamma ray, resistivity, and sonic logs. Hydrate saturations as high as 80% of pore space were estimated from the logs. Analysis of retrieved cores confirmed pore saturation estimates from the logs.

The CMR tool (a form of NMR) was effective with their petrophysical model. Using CMR data, they could calculate not only porosity but also gas hydrate saturation. To use the CMR, they did not need pore water salinity information. CMR results for hydrate saturation in pores were consistent with saturations obtained from other logs. It was concluded that the CMR is a very useful tool for quantifying gas hydrates in sediments.

JNOC has designed and built their own pressure and temperature compensated core recovery system. JNOC plans to drill 2 more test wells in the Nankai Trough area to study naturally occurring hydrates in the next two years. They plan to be production testing naturally occurring hydrate deposits within 10 years. The Nankai Trough water depth is 950 m. Hydrate bearing sediments are 200-300 m below seafloor and current estimate of gas in place in Nankai is around 200-300 Tcf.

It was pointed out that Schlumberger had developed a sensor (conventional) for the current Mallik 2002 hydrate program. The CMR log on these second set of Mallik wells worked beautifully. It was noted that we can do a good job of quantifying the location of hydrates in sediments, i.e. large pores vs. small pores by monitoring the signal from the pore water and its distribution in the sediments. Mallik 2002 data on the usefulness of this CMR tool will eventually become available to the public.

3.4 Breakout Session – Group C - Pre-Drilling Hydrate Detection Methods Drilling in and Modeling of Naturally Occurring Gas Hydrates

This session focused on the different models needed for safe drilling and operation in sediments containing gas hydrates. It looked at case histories and past experience with drilling and coring hydrates.

The following represent lessons learned that became evident as the attendees discussed various case histories.

- Capturing undisturbed samples of gas hydrates under field conditions has been difficult to accomplish.
- Smaller diameter core did not work on the first Mallik well.
- Chilled drilling mud is of assistance in preserving the cores.
- Use of a "Kinetic Modifier" (a mud modifier, Lecithin) and lower mud weights (10.5 ppg warm mud) significantly reduced hydrate problems in North Slope drilling of conventional oil wells.
- There is a need to understand the kinetics associated with mud columns.

In the brainstorming part of breakout Session C, three issues were discussed: 1) what laboratory scale tests are required to validate models? 2) what are the current protocols for taking and handling core samples? and 3) what data are required and what modeling needs to be done in order to select sites for drilling in Phase II of the JIP?

The most important results from the brainstorming session were as follows:

- Laboratory scale tests are needed to collect data on all thermal properties (conductivity, heat capacity, etc.);
- Data are also needed on dissociation kinetics with and without drilling mud, and on acoustic, mechanical, elastic, and physical properties of hydrates in sediments;

- Coring protocols used currently include keeping the core in original temperature and pressure conditions, using a safe method for transfer, transport, and storage of pressurized core barrels, re-entering the borehole with logs to test hole stability, and sampling away from the borehole; and
- Data/modeling required to select drill sites must include completing a geophysical model to quantify hydrate volumes and other overall properties, completing geological characterization to create a clear model for testing, and integrating scientific and industry objectives.

The case histories covered by Breakout Group C covered the following areas;

- Mallik (Wells 1&2);
- Various Ocean Drilling Program (ODP) Cruises;
- Alaska North Slope;
- Norway – BP & Statoil, Exxon, Shell;
- Japan – Nankai Trough;
- Russia – Messayoka Field;
- India;
- Angola (ChevronTexaco); and
- Nigeria (Statoil, Exxon).

The group noted that upcoming activities in the following areas will lead to data and knowledge that will be of benefit to the JIP. These areas are as follows:

- ODP (2002 Program) in the Gulf of Mexico;
- USGS Piston Coring Program for 2002 in the Gulf of Mexico;
- Current Canadian Mallik Wells;
- The Hydrate JIP Wells in the Gulf of Mexico;
- Alaska North Slope;

- BP (AOGC/DOE and their own initiative);
- Anadarko (along with a production test);
- India;
- Japan;
- Taiwan; and
- Korea.

Report by Frank Rack (Joint Oceanographic Institute)

Frank reported that the ODP (Ocean Drilling Program) will end September 2003. There are two proposals for future cruises, one shallow water flow and a second on gas hydrates. The ODP has a history of hydrate coring on Legs 11, 67, 76, 84, 96, 112, 127, 131, 146, 164, and 201. The DV Joides Resolution is a dynamic positioned drill ship that is used by ODP. In the upcoming Leg 204, the ODP will investigate 3 hydrate sites on "Hydrate Ridge" off the Oregon coast. During ODP Leg 204, they will be coring up to 600 meters below the mud line. The ODP data on the summer drilling program will be made public and can be used by the JIP. The Joides Resolution will be available after September 2003.

Frank next discussed 4 different types of coring tools: 1) ODP (pressured cores), 2) Fugro (pressured cores), 3) HyAce (German rotary core system), and 4) the JNOC tool.

ODP has a website where the coring tools are more fully described.

Report by Jen-hwa Chen (Chevron Texaco)

Jen-hwa stated that several boreholes were drilled offshore Norway in the late 1990's in a landslide area. It is believed that gas hydrates may have been a trigger for the landslide. However, the data gathered during drilling may not have been good enough to determine if gas hydrates were present.

Report by Arnis Judzis (TerraTek)

Arnis reported on wells drilled in Alaska, particularly the North Slope, and the Beaufort Sea. He suggested that cooling mud is sometimes economically not feasible. When drilling wells in the Alaskan North Slope, gas hydrates can create a safety hazard and idle time spent because of drilling problems can be costly. In some cases, a spud mud was used to minimize the effects of gas hydrates, causing less gas to enter the mud stream. They used Lecithin (a mud additive) to change the kinetics of the system to make drilling easier in this area. SPE Paper 38568 presents the details of the mud system. Also, information is available on Beaufort Sea Wells from the Alaska Oil and Gas Commission website.

Discussion by Lawrence Cathles (Cornell University)

In Conoco's Joliet Area, Gulf of Mexico gas is bubbling to surface (free gas) – kinetically controlled. He was not sure if making measurements, such as thermal conductivity would be a wise way to spend research funds. He said we could just assume a worst case scenario on thermal conductivity for pipeline design. He also thought spending too much time making other detailed hydrate measurements may not be cost-effective.

Report by Tom Lorenson (USGS)

There will be a new drill ship ready in July 2002 that will be used to retrieve giant piston cores in the Gulf of Mexico. One of the objectives will be to determine where are the gas hydrates in the Gulf of Mexico? Two study areas have been selected, the Mississippi Canyon Block, and a combination of Green Canyon and the Garden Banks Area. Piston coring effort (for hydrates) will occur in July 2002 in water depths of 400-1200 meters. They also can take gravity cores.

Group C next held a discussion concerning the use of pentrometers, which can be used to make measurements in the seafloor. It was stated that the Italians, Stanford University, and Fugro McClelland Marine Geosciences have all looked at this technology. The JIP may want to look at alternative measurement techniques, not just coring.

Brainstorming Session

The following three issues were discussed in a brainstorming session.

- Determine Laboratory Scale Tests Required to Validate Models.
- Determine Key Protocols for Taking and Handling Core Samples.
- Determine Modeling and Data Required to Select Drilling Sites in Phase II.

Group C discussed each issue by building lists and then prioritizing the lists by voting. The following are the results of those brainstorming sessions.

Issue #1	**Laboratory Scale Tests Required to Validate Models**
11 Votes	Dissociation Kinetics/Mud Stabilizers
11 Votes	Hydrate Thermal Properties (conductivity, heat capacity)
9 Votes	Poro-Elastic Properties (acoustic and attenuation)
6 Votes	Mechanical/Physical Properties, Shear strength
6 Votes	Electrical Properties
5 Votes	Testing Intact Cores that have never left Pressure/Temperature Stability
4 Votes	Material characterization of each sample selected
3 Votes	Uniaxial Consolidation
2 Votes	Geochemical Variables

Issue #2	**Key Protocols for Taking and Handling Cores**
15 Votes	Maintain original pressure and temperature conditions
13 Votes	Develop a safe mechanism for transporting pressurized cores
12 Votes	Re-entering the borehole with logs to measure hole stability
6 Votes	Procedures for measuring hydrate core properties after extraction
3 Votes	Quickly re-stabilize the cores if they are not pressure cores

3 Votes	Ensure an adequate number of core barrels, people, tools, are on-site
2 Votes	Clear operations plan (and Follow-up plan for Hole)
2 Votes	Pressure Maintenance System for pressurized core barrels
2 Votes	What instruments do you want on the Seafloor before Drilling?

During the discussion on Issue 2, a significant discussion evolved on the desirability and advantages of re-entering a cored hole in a timely manner to gain additional information. It was concluded that we should also run a standard logging suite whenever possible. It has also been shown that nuclear magnetic resonance logs are important in identifying natural gas hydrates.

The group then discussed the benefits of instrumenting the borehole to make long-term measurements that sample a large portion of the formations surrounding the core hole. Seismic information to relate "in hole" data such as VSP could be of benefit when trying to calibrate seismic data. Other "extended", "far away" wellbore measurements, and/or permanent well monitoring, such as acoustic measurements, volumetric electrical (ERT) measurements and borehole GPR (Ground Penetrating Radar) could be of benefit to the characterization of shallow sediments containing gas hydrate deposits.

<u>**Issue #3**</u>	**Criteria/Data/Needed to Select Drilling Sites**
17 votes	Complete geophysical model to quantify hydrate
12 Votes	Complete geological characterization and clear geologicmodel
7 Votes	Integrate scientific and industry objectives
5 Votes	Bottom profiling (Geo-hazard Studies) study
4 Votes	Historical data on area, known hydrates, gas venting
3 Votes	Moderately shallow water depths near existing facility for cost synergies
3 Votes	Multi-component seismic available to better understand the site
2 Votes	Sites with highly varied lithologies to test difference (sands, silts, clays)
2 Votes	HSE must be factored into the decision

4.0 DRILLING, CORING AND CORE ANALYSIS WORKSHOP

This workshop focused on the current state-of-the-art with respect to planning for taking cores, safety issues, core sampling and preservation and core analysis. The objective of this workshop was to determine what is currently known regarding coring in hydrates and what major gaps in technology need to be filled. Three breakout sessions were conducted as part of this workshop as follows:

- Session D1 – Drilling and Coring Well Plan and Safety Issues
- Session D2 – Core Sampling and Core Preservation
- Session D3 – Core Analysis

Agenda for Thursday, May 9th, 2002

8:15	JIP Overview	Emrys Jones, ChevronTexaco
8:30	Overview and Objectives of Modeling Workshop	Mike Smith, MMS
9:00	Overview and Objectives of Drilling Workshop	Ben Bloys, ChevronTexaco
9:30	Organization of Breakout Groups	Dave Demski, Energy Forum

Drilling Workshop Agenda

10:00	Overview of coring and core preservation	Tim Collett, USGS
10:30	ODP Hydrate coring equipment and procedures	Frank Rack, JOI
10:45	JNOC Hydrate Coring Equipment	Jim Aumann, Aumann
11:00	Fugro Coring Equipment	Gary Humphrey, Fugro
11:15	HYACE Coring Equipment	Frank Rack, JOI
1:00	Breakout Sessions for Drilling, Coring and Core Analysis	
	D1 – Drilling and Coring Well Plan and Safety Issues	
	D2 – Core Sampling and Core Preservation	

4.1 Overview Presentations

Tim Collett, Frank Rack, Jim Aumann and Gary Humphrey made keynote presentations to begin the workshop. The presentation materials can be found on the JIP website.

4.2 Detailed Results – Group D1 - Drilling and Coring Well Plan and Safety Issues

This session focused on drilling, coring and logging mechanical and safety issues, to include the following:

- Hydrate specific safety issues;
- Components of the well plan;
- Requirements for a usable bore hole;
- Drilling fluid design to include inhibitors and temperature;
- Coring tools to include barrels and bits;
- ROV for observation and or sampling; and
- Wireline logging, logging while drilling (LWD) and, Vertical Seismic Profiling (VSP).

4.2.1 Summary of Group D1Results – Drilling and Coring Well Plan and Safety Issues

This session focused on drilling, coring and logging mechanical and safety issues as it relates to hydrates. Specific issues included key components of the well plan, requirements for a usable wellbore and drilling fluid design. In addition coring and logging tools were addressed along with the role of ROVs.

Key conclusions of this workshop were:

- Regarding well planning, key issues were identified as risk analysis, the need to determine temperature throughout the circulating systems and the need for a flow chart for core analysis. In addition several sources of past well plans and related references were identified.

- Weighted and chilled drilling fluids were identified as key factors in minimizing hydrate dissociation. Freshwater was considered bad for shale stability and it was felt that hydrate dissociation inhibitors could probably improve upon Lecithin.

- Several sources of hydrate related safety plans were identified.

- Several sources of coring tools and their uses were identified. These are primarily wire-line retrieval systems that may require special drill strings, but that also provide a lot of options.

- It was concluded that the use of an ROV during drilling and/or coring was not needed or worth the money. It was unknown whether the MMS would have this as a requirement however.

4.2.2 Details of the Discussion

Concerning the requirements for a usable borehole, it was noted that one needs a gauge hole that is stable for logging. Hole stability would also be important for long-term monitoring, if the hole is to be fitted with permanent sensors, such as fiber optics behind casing to measure the temperature, or resistivity or acoustics sensors.

Concerning the well and coring plans, the planning process, including risk will have to be approved by MMS in order to receive a drilling permit. The group identified several sources of past well plans and related references. It was mentioned that the JIP will have to carefully determine the temperature throughout circulating system, keep the core in the hydrate PT envelope as much as possible. It was agreed that a flow chart for coring handling and core analysis must be generated before detailed planning can be completed.

Engineered drilling fluids will be important to the success of the JIP. Weighted drilling fluids can provide more hydrostatic pressure, which should result in better hole stability. It is also possible that chilled fluids will lead to slower hydrate dissociation. In the North Slope, hydrate dissociation inhibitors, namely Lecithin probably improve the hole stability.

Specific safety issues will exist when drilling shallow sediments containing naturally occurring gas hydrates. The group identified several sources of safety plans. A substantial HSE effort will be required to deal with pressure, flammable gas, and, possibly hydrogen sulfide.

In a general discussion, it was noted that the JIP may require dedicated holes for different objectives. For example, it may be better to drill one hole for logging, then moving over and drill a second hole for coring or instrumenting. It will be important to keep any hole as stable as possible. Because the sediments will contain shallow gas, the drilling could be risky. It may be best to log the hole first, and then design the coring program. When using wire line retrievable cores, one can retrieve 10 meters every 20 minutes. With normal coring, one can retrieve approximately 60 feet of core per hour. When pressure coring, there is a 2-hour cycle time.

4.2.3 Discussion by Jacques Bourque

A properly written well proposal should contain objectives, targets, hazards, and pore pressure information. The proposal should include the basis of design, with documentation of how all decisions were reached. The operations program must have step-by-step details of the entire drilling, logging and coring processes, all in conjunction with MMS Regulations and HSE concerns.

Concerning the risk management process, we will need to review the scope of operations, identify risks, analyze risks, mitigate risks to ALARP, prepare a risk resister, and monitor the risk plan during operations. A risk register consists of a well proposal, the basis of design, the operations program, and an end of well report.

4.2.4 Discussion by Yuichiro Ichikawa

When drilling shallow holes in zones that contain hydrates, JNOC will apply riserless drilling, with pilot holes to gain information. ROVs are used to monitor the returns on the seafloor. The pilot holes are important because the top of the hydrate may or may not be known. They also use multiple holes for coring and logging. A typical scenario might be to drill Pilot Hole No. 1, then drill Pilot Hole No. 2, followed by the Main Hole that will be cored and logged. JNOC has a Procedure/Program for its wells, but it would have to be translated into English. Once JNOC joins the JIP, they will provide the translation.

4.2.5 Discussion by Ben Bloys

When gas hydrates exist at the seafloor, drilling will be a challenge, especially the choice and properties of the drilling fluid. There will be a decision on whether to use fresh water mud or to drill with seawater. Fresh water would be more expensive and require more logistics. However, salt may cause more hydrate dissociation. Pumping rates during coring will be fairly low. Without a riser, oil based mud is no an option.

In the ODP, core is usually taken with simple, clear fluid made using seawater. Core recovery should be better in permeable, unconsolidated sediments if the coring fluid quickly builds a thin tough filter cake, by adding bentonite for example.

Ben suggested that the kinetics of hydrate dissociation can be slowed by using water-soluble polymers. Also, higher mud weight increases hydrostatic pressure and slows hydrates dissociation. The mud weight, however, will be limited by fracture gradient.

4.2.6 Discussion by Doug Kinsella

Doug Kinsella stated that thermal equilibrium will be established between the core and drilling mud during the coring operation. It would be best to maintain the core in the proper pressure and temperature stability zone where hydrates will exist. There will be an exchange of reaction/latent heat during gas hydrate dissociation and/or hydrate formation.

Corion Express successfully delivered over 97% recovery of the Hydrates cored on the Mallik 2002 project in the arctic, where ambient temperatures are quite low. They found out that an anti-milling feature lead to maximum core recovery. A newly designed low invasion core bit lead to increased ROP and decreased fluid invasion. The coring of the hydrates found in the sandstone in Mallik was fairly easy and routine.

4.2.7 Discussion by Brian Jonasson

The Joides Resolution (JR) is a fully dynamically positioned drillship. It has three coring systems, the Advanced Piston Cover (APC) which in soft sediment usually has 100% recovery, the Extended Core Barrel (XCB) for hard sediment, and the Rotary Core Barrel (RCB) for hard rock. The JR rig floor is equipped to move when needed to minimize the bending stresses on the drill pipe. Complete details of the capabilities of the JR can be found on the ODP website.

Typical operational procedures for a shallow well in deepwater would be to jet in casing as a conductor, run in hole with the rotating head/mud lift package, core 1,000 to 2,000 ft below mud line, then abandon the hole using heavy mud and cement plugs.

4.2.8 Discussion by Derryl Schroeder

The Advanced Piston Coring Methane Tool will give a good indication of the amount of gas in the core. You may be able to find out where the gas hydrates are located and perhaps learn something about hydrate saturation. The Modified Pressure Core Sampler can be used to capture hydrate, and graph where the gas hydrate was located.

For the ODP, they normally log any hole deeper than 300 meters. They also drill more hole after the base of the hydrate zone has been penetrated. They may decide to case the hole, log it and use the data to drill other holes in the area.

4.2.9 Discussion by Timothy Collett

Since gas hydrate is a solid, we can use acoustic data to determine where gas hydrates are located. We should be able to determine hydrate saturation using acoustic data.

Nuclear Magnetic Resonance (NMR) is a tool that is now being used to determine gas hydrate saturation, with even more accuracy than using acoustic data. The key to accurate saturation estimates is, however, obtaining quality data is the field.

In the arctic, one can use weighted, chilled mud with additives and control the drilling parameters to obtain a gauge hole. Then the logs once obtained will be more accurate than similar holes in deepwater that may not be in gauge.

4.3 Detailed Results – Group D2 Core Sampling and Core Preservation

This session focused on the challenges of safely preserving hydrate bearing cores in their original downhole condition and sampling them for lab analysis. Specific topics included pressure and temperature maintenance, shipping, safety, transportation and on-site sampling.

Key conclusions of this workshop were:

- To design core sampling and core presentation work plans, the JIP must develop a flow chart that clearly enumerates what measurements will be needed, where, when and by what process they will be obtained.

- Only after knowing exactly how much core is needed, where the core is needed and for what purposes the core will be used can the JIP come up with a realistic plan to preserve and transport that core.

- Several gas hydrate coring projects, Mallik 2L-38, ODP Leg 204 and Anadarko's Arctic Project, have just been completed or will be conducted soon. The JIP should watch these projects very closely and apply all best practices.

- Preserving core temperature is critical. There was some concern identified, however, over the use of liquid nitrogen to accomplish this due to the potential of the nitrogen to change the hydrate properties due to molecular interaction.

- Transportation of pressurized core samples should be by land or sea and not by air.

- Once the core is taken, there was a high degree of interest in instrumenting the hole and surrounding seafloor and gathering additional data over time. This should help integrate the core data and provide information on the dynamics of hydrate sediments.

This session focused on the challenges of safely preserving hydrate bearing cores in original downhole conditions and sampling the cores for laboratory analyses. The key issues addressed by the group were pressure and temperature maintenance, stabilization for shipping, on-site sampling, safety plan issues, transportation/logistics issues, and integration of coring and sampling devices.

To design the core sampling and core preservation work plans, we must first develop a flow chart that clearly enumerates what measurements will be needed, where, when and by what process they will be obtained. We need to know 1) what tests are going to be run, 2) when those tests are going to be run, 3) where those tests are going to be run, 4) how long the tests will take and 5) how much core will be required to run the desired tests. Only after knowing exactly how much core is needed, where that core is needed and for what purpose the core will be used can the JIP come up with a realistic plan to preserve and transport the cores.

The group discussion focused on the challenges of maintaining down hole temperature and pressure of the core sections to ensure stability of the hydrate from the moment of recovery, through sampling, shipping and, longer term, in the laboratory. Fortunately, several gas hydrate coring projects have just been completed or will be conducted soon, including the Mallik 2L-38, the ODP Leg 204, and Anadarko's Arctic project, that are testing and defining state-of-the-art processes and provide a critical base line for JIP operations. The JIP should watch these projects very closely and apply all best practices to our project.

To preserve gas hydrates samples for laboratory analysis, one key parameter that must be controlled is the temperature at which the core is maintained while coring, retrieving, transporting and testing. While liquid nitrogen is generally used for cooling hydrates, more research is needed to determine the effects of using nitrogen in a liquid versus gaseous state to address concerns about stability of the hydrate properties. Several participants suggested that the core in contact with liquid nitrogen could change with time due to molecular interaction.

Pressure maintenance is also critical, but re-pressurization of samples is a viable option. With re-pressurization, one issue that needs further investigation is the choice of gas used (dissociated gases, inert gas, methane or other gases) and its effects on the hydrates.

In regard to transportation, the experiences from the Mallik project, clearly suggest that transportation of pressurized samples should be by land or sea and not by air. Additional data concerning the DOT regulations are available from the Mallik project and from the DOT Website.

Finally, to complement and integrate the core data, there was an interest in continuing to gather geophysical information from the wellbore, after coring is completed, by instrumenting the hole and the seafloor around the hole with sensors that could gather data over time, i.e. CORK, Circulation Obviation Retrofit Kit.

4.3.1 Details of the Discussion

Stephen Holditch began the discussion with a general comment that the JIP needed to be sure its coring plans were reasonable. In the JIP proposal for Phase II, two wells would be drilled at the chosen site. One well would be drilled for logging and looking for gas hydrates. A second (twin) well would be drilled to core the hydrates. For the breakout session, we began with the assumption that we know where to core, but in fact, the JIP would appreciate insights from the participants on this issue. Holditch asked the participants to suggest, as we go along, any ideas on how to improve the selection of intervals to be cored. On the upcoming ODP Leg 204 well, plans are to core one well completely with simultaneous logging while drilling (LWD), at a location with a strong BSR.

Bill Winters made a presentation on the Woods Hole laboratory for testing natural gas hydrate cores. He described what they did on the MALLIK project and the capabilities of GHASTLI (Gas Hydrate and Sediment Test Laboratory Instrument). Sediment samples were shipped to the Woods Hole laboratory for analysis. Bill discussed how hydrate cores were sampled and handled. Bill suggested that there is no consensus on core handling. Samples have been flown in to the laboratory, but Bill did not feel it was the best way because samples in pressurized vessels were generally not suitable for air travel. Environmental temperatures are also an issue in transportation of gas hydrate core samples. Cold ambient temperatures, experienced in the Mallik 2L-38 project, were helpful in hydrate preservation, more so than the hot Gulf Coast summer temperatures will be in the planned JIP project.

Self-preservation of the hydrates by maintaining cold temperatures is key. A diagram was shown of ways to preserve gas hydrates cores using liquid nitrogen or pressure vessels. There are problems with storing sediments containing gas hydrates directly in liquid nitrogen without encapsulation, but this is the practice that is most widely used today. There are less problems when storing pure hydrates in liquid nitrogen. Nitrogen changes the properties of the samples and dissociation can occur as temperatures rise.

A good method to preserve hydrate cores is to use pressure vessels. However, there are a limited number of suitable vessels available. Options for pressurization include the type of gas (using inert gases, non-methane gas hydrate forming gas, or methane), pressure and temperature. Once pressurized, transportation of samples must be in accordance with Department of Transportation (DOT) regulations. Bill has experience in this area and has more information that can be shared with the JIP. Shipping must comply with DOT regulations, but for small quantities (CFR 173.306), some exemptions are available. Some carriers do not like to transport pressurized vessels at all.

There was more discussion of how to preserve hydrate cores using nitrogen in either liquid or gaseous form. The discussion continued concerning how to preserve cores. Frank Rack asked, "Is the method the same for hydrate sample in shale or sand?"

Steve Kirby made a presentation about the stability of hydrates in liquid nitrogen. The effects of long-term storage in nitrogen are unknown. No studies have been published as far as he knows. Kirby explained how they make methane hydrate from pressured granulated ice. Steve Holditch asked if liquid nitrogen is the best choice. Steve Kirby said it is reliable as long as you use dry shippers. It can be sent anywhere. Preliminary work has been done on tests on anomalous preservation regime.

The group discussed ways to control core temperature while coring and pulling the core to the surface. Pressure, temperature and time are all important factors. Bill Winters said good control of the drilling mud temperature and core recovery-time was an important factor. Kirby suggested larger samples might be able to keep the temperatures low for longer periods.

Frank Rack made a presentation on how to actually use coring systems on a vessel. Three pressure coring systems will be used on the next ODP expedition. There are issues regarding space and layout on board the ship. They are working to resolve this. Also, once the core is retrieved, it must be removed from the coring tool first before obtaining another core. The logistics of core handling on the surface are very important and must be well coordinated.

Introducing new tools requires a learning curve. Once the core is obtained, it should be put in a cold room within 15 minutes for microbiology analyses.

Instrumentation on the ODP ship is very advanced. Drilling accelerators have to be used with the coring system. Personnel are needed to work with the tools, i.e. strip out and clean them and get them ready for the next coring. Once a core is obtained, identification of the hydrates is key. Liquid nitrogen would be put in the plastic liner of a 9½ meter core.

ODP Pressure Core Samples allow them to go to all water depths. FUGRO and HYACE are compatible with the ODP drill pipe, but the Japanese system is not compatible. The goal is to be able to use them on other vessels, and some are also wireline deployable. HYACE Laboratory Transfer Chamber is a pressure vessel constructed from a glass reinforced plastic tube with steel end-caps. The core is transferred under pressure and logged under pressure. An integrated approach should be taken in the analysis so that geophysical, physical and microbiology properties can be taken into account.

After the presentations discussed above, the group then focused on pressure and temperature maintenance, stabilization for shipping, on-site sampling, safety plan issues, transportation and logistics, and integration of coring and sampling devices. While many issues were identified and are enumerated below, specific planning for core handling and preservation needs to begin with a clear understanding of what information or specific data was needed from the core and when and where it could be obtained (on-site or in a remote lab). Once a flow diagram for testing has been developed by the JIP, then a plan for pressure and temperature maintenance, stabilization, safety, etc., can be defined. Additionally, state-of-the-art procedures for core handling were being tested in several projects, i.e. the upcoming ODP project, a hydrate coring project in Alaska by Anadarko, and additional data was available for review on the MALLIK project. The JIP should monitor and utilize the information gained on these projects to further develop specific core handling procedures.

One issue that was added to the agenda was CORK (Circulation Obviation Retrofit Kit). There may be cost-effective benefits to be gained by instrumenting the wellbores and the surrounding seafloor, after coring, to make additional measurements. Measurement of sonic, resistive and other properties on a large rock volume over time around the wellbore could provide valuable information.

Finally, the group discussed the need to understand the degree of accuracy or precision that will be needed in obtaining data. If these issues are clearly defined, by those using core data, it would be useful in planning for handling of hydrate cores.

4.3.2 Core Sampling and Preservation

A general discussion was held concerning "Core Sampling and Core Preservation". The first area of discussion concerned "Pressure and Temperature Maintenance" of the core samples. The group agreed that pressure and temperature maintenance requirements depend upon **what tests** are going to be run, **when** tests will be run, and **where** testing can be done, and **how** long the test will be. It was suggested that the "State of Art" is defined in a JOI Report (see website: http://netl.certres.com - Login NER – PW ARCHIVE - HYD_00037_2001.pdf) that is available from their website. It was also clear that ODP Leg #204 will provide a great test of current data collection, test tools and procedures for coring, core sampling and core preservation.

Westport is publishing a best practices manual for coring (a DOE sponsored compilation). The report will be available in July 2002. This is public information that can be made available on the JIP website. Jon Burger at Westport Technology should be contacted for additional information.

One nice feature of the ODP ship (JR) is that a majority of necessary measurements using the core can be made with the laboratory equipment that is on-board the JR. Therefore, pressure and temperature stabilization issues are not so severe. If cores containing gas hydrates have to be transported from the drillship to an onshore laboratory, the stabilization issues become very critical. Maintaining low temperature is very important for preservation of the hydrates in the cores. It is possible that unpressurized cores can be re-pressurized once they are brought to the surface. It also might be possible to capture samples of the native gasses for re-pressurization of the cores to stabilize hydrates.

As the discussion continued, it became clear that no one can come up with a plan for core sampling and preservation until a very detailed flow chart on what will happen to the core from

A-Z can be defined. Once the JIP knows exactly **what tests** are going to be run, **when** tests will be run, and **where** testing can be done, **how** long the test will be, and **how** much core will be needed, then the JIP can develop a plan for core sampling and preservation.

The discussion next shifted to the use of liquid nitrogen as a means of preserving the core. A key question was "Does liquid nitrogen alter the core and hydrate as a function of time?" It was concluded that more tests will be needed in the laboratory with laboratory generated hydrate samples before this question can be fully answered.

4.3.3 On-Site Sampling

The JIP will be monitoring both ODP Leg #204 and Anadarko North Slope Project for progress is the area of on-site sampling and technologies, and procedures that can be used by JIP. The JIP will need to develop a plan on how much core can be cut and effectively managed under pressure. In addition, microbiology issues and needs should be reviewed and included in the on-site sampling planning. Microbiology measurements have been very beneficial to the understanding of seafloor samples and gas hydrate samples in prior ODP legs.

The ODP JR uses a thermal mapping/camera on-site to identify where hydrates are located in the core. The thermal system is very useful in determining what portions of the core need to be sampled early so it can be preserved early. To determine the time required to core the samples, get them to the surface, run the thermal system and get the samples into containers, one can refer to the ODP coring time estimator (on website).

4.3.4 Safety Plan Issues

The JIP should use the current ODP Safety Plan as a starting point for writing its own safety plan. Materials safety sheets for all laboratory processes are required, and ODP has much of this already done. Pressurized samples will have to travel by land or sea – not by air. It will be necessary to define a "Sample Request Process" by all scientists who want to use core. The results of this process can then be used to determine operational, transport and storage/archive issues in core handling.

The JIP should look at the ODP processes for data handling items such as relational data bases, tracking systems, bar codes, etc. The JIP can also look at the "ODP Pre-cruise Planning Process" to be sure the JIP includes all necessary details in its field plan.

4.4 Detailed Results - Group D3 Core Analysis

This workshop focused on what type of core analysis and lab testing should be performed on cores gathered in Phase II of the JIP, and what were the relative priorities for the testing. This included on-site core analysis and analysis of the cores while under pressure and in the lab. Properties to be considered included mechanical, geochemical, physical and electrical.

Key conclusions of this workshop were:

- Three primary reasons for the need of accurate core analysis were identified. These were the need to 1) assess hydrate impact on wellbore stability, 2) assess hydrate impact on pipeline stability and 3) to calibrate remote sensing data (e.g. seismic).
- The state-of-the-art for coring is currently defined by the Mallik wells and ODP Legs 201 and 204.
- The primary gaps in coring are 1) obtaining representative natural cores, 2) synthesizing representative laboratory cores and 3) gaps in testing protocols.
- A list of important mechanical properties needed from core analysis was developed. This included stress strain curves, moduli, resistivity, porosity, permeability, hysteretic phenomena and compaction properties.

A **common theme** emerged. It was clear that there is a significant opportunity for the JIP to improve the state of knowledge of naturally occurring gas hydrates, by gathering in-situ seafloor and/or wellbore data, via downhole instrumentation, over time. There is an almost a total lack of in-situ data taken over an extended period of time. The use of instrumentation on the seafloor and/or in wellbores could provide valuable insight into the stability of hydrates over time, and a better understand of the process of dissociation.

This session focused on the types of laboratory testing that should be scheduled and their relative priorities. The key analyses that will be needed are measurements of mechanical properties, geochemical properties, physical properties, core handling and analysis procedures for core samples under pressure, development of an on-site core analysis plan, and other measurements of the core such as spectral gamma ray measurements and electrical property measurements.

It was agreed that there are three reasons for core analyses for this project. One reason will be to "Assess hydrate impact on wellbore stability". To do this, the JIP will need to determine what parameters are significant so they can be measured in the laboratory. The JIP also needs to determine when preventative measures will be required to stabilize the wellbore. The philosophy should be to stop any wellbore stability problems before they begin.

The second major reason for doing core analysis will be to "Assess hydrate impact on pipeline stability". To do this, the JIP must determine how seafloor hydrates respond to heating and what parameters are significant? The JIP also needs to consider the question of "When do you need preventative procedures?" The philosophy should be to stop any seafloor stability problems before they begin.

The third major reason for doing core analysis will be to make measurements that can be used to calibrate the presence of gas hydrate by remote sensing (e.g. seismic).

From the March 14-15 Data Collection Workshop, the critical core properties were identified. The main use of the critical core properties were identifying on the basis of their uses in Hazard Identification (H), Exploration (E), or Production (P) activities.

Thermodynamics in porous media forms the foundation for all the measurements. Specific critical properties are as follows:

- Dissociation kinetics (H) (P),
- Permeability/flow (P),
- Thermal properties (H),
- Electrical properties (H, E, P),

- Soil Texture, aggregates, morphology, (E, P),
- Mechanical properties (H),
- Seismic properties (E),
- Composition/hydration number (P),
- Bio-geochemical/microbial (E), and
- Final hydrate saturation in sediments (H, E, P).

The important mechanical property measurements involve stress strain curves to determine the linearity of the measurements and the failure modes of the test samples. Static and dynamic moduli measurements will also be very important in determining the mechanical behavior and strength of the core samples with and without gas hydrates.

4.4.1 Details of the Discussion

Each person in attendance introduced themselves, then Dendy Sloan made a few initial comments to frame the breakout session discussions. The following questions were placed before the session to develop answers.

- What data from the cores will be needed by the JIP?
- What are current technology gaps in making core analysis measurements?
- What has been done in measuring core containing hydrates? What can be done?
- What to do on-site with cores?
- What to do off-site in labs? Which labs?
- What logging can be done at the surface (in cold room)?

4.4.2 Discussion by Dendy Sloan

A core with gas hydrates contains large volumes of gas. The core can extrude from core containers (e.g. observations from ODP Leg 164) due to pressurized gas pockets produced from partial melting of the gas hydrates in the cores during core recovery. These factors demonstrate that hydrates are a safety issue and cores need to be treated safely. Two-thirds of the hydrates naturally occurring in the Gulf of Mexico are structure I and 1/3 are structure II. This is different from most natural hydrate occurrences around the world. Thermogenic gas hydrates seem to be common in the Gulf of Mexico.

A question was put to the breakout session, asking them why they were participating in this particular breakout session. They answers were varied and can be found in the detailed report on the JIP website.

A second question was posed to the group. Everyone was asked to identify at least five properties that should be measured in cores containing natural gas hydrates. They were asked to specify those properties that should be measured on-site and those that should be measured later in laboratories off-site.

4.4.3 Lewis Norman

First, Lewis assumes that all measurements will be made at restored state (in-situ) conditions, then he stated his list as follows:

- Analysis of composition of all the phases;
- Mechanical properties, such as stress strain as a function of changing temperature and pressure;
- Multiphase permeability to be used to estimate production of gas and water;
- Decomposition kinetics of the hydrates in the cores;
- Sensitivity analysis to determine what is important; and
- Do we need to focus on origin issues? How did the hydrates get there? If we focus on microbiology, can we better understand what's out there and why? What is the value?

4.4.4 Tim Collett

- Lab work should have measurements representative of natural conditions.

- We'll never have a pristine core from nature.
- How do we translate measurements between different labs?

4.4.5 Ken Gray

Ken also assumes that all parameters are measured at in-situ conditions.

- Test hydrostatic conditions and triaxial and uniaxial compaction in a cyclic manner to see hysteresis – stress strain, compressive failure, resistivity and permeability, wave (Vp and Vs) velocities.
- Do tests in laboratory environment so you can control all the variables and see the relationships between the parameters.

4.4.6 Barry Freifeld

- Need to know pressure and temperature history of the core.
- Sediment textural fabric and hydrate distribution – Linear X-ray on-site and microtomography off-site.
- Stress strain measurements as a function of hydrologic and thermal coupling are paramount.
- Thermal conductivity and heat capacity of hydrate core samples.

4.4.7 Brian Maggard

- Core data is ground truth – a way of calibrating the well. Should include seismic attribute analysis as well as logs.
- Log analysis. Can we look at electrical resistivity or chlorinity and infer saturation?
- Pore volume compressibility and how the effective permeability changes with dissociation.

4.4.8 Bayram Kalpakci

- Measure the simple things, such as mechanical and acoustic properties.
- Electric, acoustic, thermal and NMR data for wellbore stability.
- Dissociation rates and fluid compositions.
- Properties of sandy layers such as permeability, porosity, grain size, do X-ray CT.

4.4.9 Devinder Mahajan

- Do synthetic samples first, and repeat in another lab to within a few percent.
- Dissociation kinetics, permeabilities, porosities.
- Microbiology is dependent on what the hydrocarbons are doing, e.g. the sulfate-reducing zone.

4.4.10 Cog Ochiai

- Vp and Vs wave data to correlate with hydrate saturation.
- Density and neutron calibration data for correlation with wireline data.
- NMR/CMR for porosity and hydrate saturation.
- For onsite would like to have core temperature measurements as routine work. Can be used to identify hydrates through temperature anomalies.

4.4.11 Bradley Julson

(All on-site measurements)

- Physical properties, volume of gas evolved per unit volume of sediment from core, which gases are evolved?
- Pore water chemistry.
- Microbiology to determine species controlling systems.

4.4.12 Tim Collett

(Assume measurements are made under in-situ conditions for sediments, water and gas hydrates. Want as much data collected on-site as possible.)

- Proton NMR properties of gas hydrate bearing water/sediments to get on-site relative permeability, gases. With CMR tool.
- Acoustic parameters under the same conditions. This is for remote sensing which will be seismic in the ocean.
- Thermal conductivity under the same natural conditions.
- Relative permeability in porous media.
- Strength of the sediments.
- Sample characterization.

4.4.13 Jim Chitwood

(Reviewing notes from March workshop.)

- Anomalous self-preservation is an issue not previously mentioned.
- Solubility of methane in water at high pressures is important information.
- We need to identify input parameters for wellbore stability calculation programs, and then determine how hydrates change or impact these parameters.

4.4.14 Ken Gray

Question: In conventional wellbore stability what variables are crucial?

Answer: The degree to which mechanical behavior is non-linear with stresses.

Question: To what degree are models known today in companies or JIPs?

Answer: Dick Plumb of Schlumberger is taking the lead on wellbore stability modeling within this JIP

4.4.15 Barry Freifeld

- TOUGH2 model coupled with industry standard FLAC3D code.
- Need a constitutive model: stress strain curve, coupled with thermal and hydrologic properties with time.
- These cores are poro-elasto-plastic material and measured values may vary with time.

4.4.16 Lessons from Mallik-2002 Experience

According to Tim Collett, it is necessary to closely track the pressure, temperature, and composition history of the cores with time. The reason for cutting the core will determine how each core should be handled prior to making the core measurements. The JIP must plan in advance what studies will be done on the cores, what conditions will the cores need to be stored under for each of those studies, how many core samples are necessary for each study. In a marine environment without a riser, your options are more limited. In the Gulf of Mexico, you may not be able to accurately control pressure and temperature as well as in the Mallik situation due to the recovery through a water column.

According to Bill Winters, hydrate saturations from the Mallik cores were approaching 80% of porosity. Where they had high gas hydrate content, they had low temperatures. The only place where they had negative temperatures was where hydrates were located in the core. The cores with the coarsest grain sizes had the highest hydrate content.

On the 5L-38, they had wireline coring tools and better control of the circulating mud temperature. They used chilled mud to keep the cores cold, which provided for better core recovery. They did not have pressure coring on 5L-38, but the coring program was still very successful. In the Gulf of Mexico, hopefully, we will have pressurized cores. Mallik 5L-38 generated 30 different cores. These will be analyzed in various labs.

4.4.17 Core Recovery and Processing at Mallik 5L-38 (Aluminum Core Liner)

The following basic tests and preparation were performed on-site:

- Video scan was taken of the core.
- Temperature probes were installed for history logging.
- Infrared thermal imaging cameras were used to capture photos that were used to identify regions with high hydrate concentrations in the cores.
- 'Quick and dirty' tests were done to see how much hydrate was in the sediment. E.g., take a chunk of hydrate + sediment, weigh it, and drop it into water and measure the amount of gas that came out and from the mass of the sediment; they were able to do quick and dirty estimates on hydrate content of sediments.
- Preliminary geophysical work was performed on-site.
- Observed core cementation with hydrates was a strong indicator of what core areas had high concentrations.
- Preservation of gas hydrates lasted for several weeks especially if an ice rind formed. Ambient temp –20 to –40 C.
- Pressure vessels were frozen and charged with methane and nitrogen gas.
- Microbiology samples were collected.
- Canned gas samples from the dissociated hydrates were collected.
- Core storage used both dry shippers and wet shippers (alternatively) to minimize the impact of unexpected deterioration during storage.
- Germany GeoForschungsZentrum Potsdam (GFZ) from Potsdam had a good lab on-site for measuring thermal conductivity, electrical properties, etc., of the cores.

- There were two permeability indicators during the Mallik 5L-38 production test: NMR tool which needs to be calibrated more and the Modular Dynamic testing (MDT) tool which looks at pressure drop for a given flow rate and that yielded pretty good permeability numbers.

4.4.18 The Core Was Divided by Sedimentology and the Following Measurements Were Made.

- Physical properties: water content, grain density, porosity bulk density, grain density (porosity and bulk density), grain size.
- Frozen core: thermal conductivity, Vp, magnetic susceptibility, electrical resistivity (on cores without gas hydrate).
- Pressurized cores: GFZ sophisticated field lab system from Potsdam was used to measure: Vp, Vs, and electrical resistivity.
- Home country laboratories: water chemistry, microbiology, gas chromatography composition, isotopic fractionation, CH characterization, SEM Imaging.

4.4.19 Steve Kirby, USGS – Hydrates in Sediments

Acoustic properties of hydrates in sediments are important for exploration. P and S wave speeds are important since seismic seems to be the primary hydrate detection method today. These are also important for interpreting acoustic well logs.

Sonic velocity may not necessarily tell you hydrate saturations unless we have some other information about how the hydrates occur in the sediments, i.e., are they in pore space or are they acting as cement, etc. This will determine the mixing rules necessary to accurately interpret wave speeds of hydrates in sediments. Mike Helgerud's (Stanford Rock Physics group) thesis suggests that mixing rules necessary to determine the effect of hydrates in sediments on wave speeds are certainly non-linear.

An approach to the problem would be to take the four conformations for hydrate-sediment occurrence from Mike Helgerud's thesis. He has a rock physics model for each conformation. We should conduct tests for each conformation to back out the mixing rules for hydrates in sediments. It will be time consuming to do all those measurements for hydrates in sediments. However since the P and S wave speeds in sI hydrate are very comparable to those in ice, perhaps ice can be used as a surrogate for hydrates in sediments to develop an understanding of the mixing rules. Actual hydrate core samples would be used as ground truth checks at various points in the test matrix for quality assurance. This approach should significantly reduce experimental costs to understand hydrate acoustic properties in sediments.

It will be interesting to further form hydrates from that ice + sediment mixture and analyze the results obtained. Starting with ice will be a more suitable to tackle the wave speed problem in the timeframe of the JIP.

Mike's thesis is available in *.pdf format from the Stanford University website.

4.4.20 MALLIK 5L-38

CORE-RELATED ANALYSES
Courtesy: Bill Winters, USGS

Physical Properties
Moisture content
Grain density
Grain size
Porosity
Bulk Density
Mineralogy
Shear strength
Plasticity
Thaw consolidation
Hydraulic conductivity
Petrophysics

Geophysics
Dielectric measurements
Electrical resistivity
P-wave velocity
S-wave velocity
Natural gamma
Magnetic susceptibility
X-ray diffraction

Thermal Properties
Thermal Conductivity
Calorimetry

Specialized Gas Hydrates
P-T stability thresholds
GH dissociation studies
GH habit
GH saturation
Molecular chemistry

Gas Geochemistry
Gas (flowed)
Gas (nobel)
Gas geochemistry-cuttings
Gas geochemistry-core
Gas isotopes

Pore Water Geochemistry
Pore water/salinity
Pore water geochemistry
Pore water isotopes

Organics
Forams-cutting
Forams-core
Geochemistry cuttings
Macrofossils
Microbial communities
Pollen cuttings
Pollen
Total organic carbon
Trace elements bg

4.4.21 Professor Ken Gray's List of Mechanical Properties

Gulf of Mexico Naturally Occurring Gas Hydrates JIP

Needed/Desired Laboratory Test Data

Simultaneous measurements of parameters and quantification of hysteretic, coupled behaviors are needed. Whenever possible, measurements should be made under identical conditions, on the same specimen, with repeated test sequences. Various loading and deformation paths are required to obtain data needed for different models/simulators. Essential load paths include: hydrostatic, triaxial, uniaxial compaction (constant lateral deformation), polyaxial, hysteretic (cyclic), and creep loading. Some loading paths do not encompass rock failure, others require strength and take-to-failure loadings. In-situ rock behavior parameters are highly coupled; change one and others will be changed as well, sometimes in ways that are difficult to understand and quantify. In addition, measurements should encompass before, during, and after phase alteration situations. Data should be obtained for hydrates alone, poorly consolidated host rocks/soils, and combination mixtures thereof, including quantification of cementation effects.

The tests listed could provide numbers and/or estimates for various parameters such as: static and dynamic Young's moduli and Poisson's ratios; compressibilities; compaction coefficients; cohesive strengths; angles of internal friction; rock-to-rock friction coefficients; grain/cement interactions; transport properties; fracture/failure initiation stresses; leakoff parameters; constitutive behaviors and correlations; failure/stability surfaces; etc. Some of the parameters could and should be compared to data from various logging, MWD, LWD, PWD, and seismic information. Much of it would be useful in future, permanent-sensor monitoring technologies.

A partial list of the measurements includes:

- Phase stability in sediments from PVT measurements.
- Longitudinal and lateral stress strain curves.
- Tensile, shear, and compressive strengths.
- Failure/stability envelopes.

- Crack initiation and crack tip mechanics/parameters.
- P and S-wave velocities.
- Electrical properties.
- Bulk, pore, and matrix compressibilities.
- Porosity.
- Permeabilities (gas, water, absolute, relative, hydrate content, phases).
- Loading-path dependent compaction coefficients.
- Thermal parameters and behavior.
- Time-dependent behavior.
- Pressure solution effects.

5.0 MODELING, MEASUREMENTS AND SENSOR WORKSHOP

The workshop on modeling, measurements and sensors focused on the current state-of-the-art with respect to the stability of hydrate sediments, data required to improve modeling, the impact of local seafloor instabilities and the use and role of seismic and reservoir modeling to improve our understanding of hydrates. The objective of the workshop was to determine what is currently known in these areas and what the major gaps or unknowns are. Three breakout sessions were conducted as part of this workshop as follows:

- Session M1 – Wellbore Stability
- Session M2 – Modeling Seafloor Instability
- Session M3 – Seismic Attributes and Verification of Seismic Analysis

Prior to starting the breakout sessions, a series of overview presentations were made.

10:00 am "Predictive Numerical and Effective Media Models of Gas Hydrate-Bearing Sediments" by Carolyn Ruppel, Georgia Tech

10:30 am "Kinetic Models of Hydrocarbon Gas Generation and Venting" by Larry Cathles, Cornell University

11:00 am "Sensors and Measurements" by Bob Kleinberg, Schlumberger

5.1 Summary of the Overview Presentation

The presentations by Carolyn Ruppel, Larry Cathles, and Bob Kleinberg can be found on the JIP website.

5.2 Breakout Session M-1 on Wellbore Stability

This breakout session addressed stability of hydrate bearing sediments as it relates to wellbores. Specifically, it addressed what is known about current wellbore stability models, what field data is needed to improve these models and what tests could be run in the Phase II test wells to improve our wellbore stability concepts and models.

Key conclusions of this workshop were as follows:

- A comprehensive list of known physical properties of hydrates, as it pertains to wellbore stability were identified.
- Five high priority areas, where additional data on the properties of hydrates is needed were identified. These related to

  1) kinetics of hydrate dissociation,

  2) acoustic properties,

  3) distribution of hydrates in pores,

  4) mechanical properties, and

  5) heat flow data.

- Relating the data from above to wellbore stability predictions or modeling is a key challenge.
- Several data sources were identified regarding past or ongoing studies with respect to wellbore stability, and
- A valid model for wellbore stability does not appear to exist at this time and there was not agreement on whether one was needed or possible to develop in the JIP's timeframe.

This session considered the stability of hydrate bearing sediments, the data required to improve modeling, and what can usefully be collected from the test wells. It was also concerned with

- What is known about the physical properties of these sediments,
- Who has the data,
- What is known about the current models and their ability to handle unconsolidated hydrate bearing marine sediments,

- What features need to be added,
- Hydrate dissociation modeling issues,
- Equations for describing low strength soils,
- What field data are needed to validate the models,
- What lab work can supplement the development/validation of the models,
- What tests can be run in the test wells drilled in the 2nd phase of this JIP before final abandonment to check wellbore stability concepts.

5.2.1 Detailed Discussion

The focus for the breakout session was hydrate-bearing sediments, primarily in the region around the wellbore. The questions addressed were:

- What is known about the physical properties of these sediments?
- Who has the data?
- What data are needed?
- Where should the data come from?
- What more do we need to understand about wellbore stability?
- What do we need from the JIP?

The breakout session participants identified the following properties of hydrates as being reasonably well known. Also shown is the location or source of the data:

- Acoustic velocities – Menlo USGS
    - Both shear and pressure waves
    - For sediment/hydrate mixtures
- Mechanical properties – LLNL
    - Bulk and shear modulis on pure hydrates

- Thermal properties – Menlo USGS and Georgia Tech
    - Conductivity in hydrate and sediment mixtures. No heat capacity or thermal diffusivity data is available.
- Electrical properties – common
    - Resistivity properties are generally and widely known.
- Impact of seawater – USGS
    - Seawater has negligible impact since hydrates are formed in high salinity subsurface brine
- Kinetics of dissociation – JNOC Chiba, Menlo USGS
    - Impact of grain size and mud additives on kinetics of hydrate formation and dissociation for both synthetic and natural sample
    - Data on pure hydrates only.

The participants in the breakout session also identified the following sets of natural gas hydrates field data:

- Cascadia Margin – Ocean Drilling Project (ODP)
- MacKenzie Delta – USGS, Canadian Geological Survey and others
    - Well drilled, cored and logged in 1998
    - Routine logs, including dipole and sonic
    - Second well drilled in 2002 (still confidential)
    - Includes MDT and production test from circulating hot water
- Nankai Trough – JNOC
    - Well drilled, cored and logged in 2000
    - Includes all routine logs

- o Well drilled, cored and logged in mid-1980s
- o Includes all routine logs

5.2.2 Additional Data Needed

The participants in the breakout session spent considerable time discussing the needs for additional data. After listing all areas of need, the session participants voted on the most important. Five areas surfaced as having the most critical need:

1. Kinetics of hydrate dissociation. We need to understand dissociation of pure hydrates as well as hydrates in sediments. Existing USGS data are complex and theories do not exist to explain the data. Surface effects at wellbore and behind pipe are particularly important. Existing sources of information on the kinetics of hydrate dissociation are Menlo USGS (LBNL with cat-scan data), GTI in Chicago, JNOC in Japan, Westport in Houston – without sediment, hydrates mixed with light and heavy oil, TAMU in College Station, and Colorado School of Mines in Golden, CO.

2. Acoustic properties. Acoustic properties are needed to interpret seismic data and acoustic logs. Existing sources of data or information are USGS in Woodshole on cores, Stanford/USGS Menlo on synthetic samples, GTI in Chicago on synthetic samples. Other laboratories that can work on core samples as well are Williamson in Seattle – passive seismic to get P and S velocities using microseismic events, and Westport in Houston on synthetic samples. Additional needs from the JIP are preserved core samples containing hydrates under representative conditions, vertical Seismic Profile data, seismic while drilling measurements, dipole sonic logs and MWD (porosity, permeability, hydrate/fluid saturation) data and results.

3. Distribution of hydrates in pores. It is important to determine the location of hydrates in pore space; specifically, are the hydrates lining pore walls or are they isolated in the pore space. Cat-scan and laser imaging can be used to see the hydrates in the pore space. Existing sources of data or information are GTI in Chicago using laser imaging, USGS – LBNL in Berkeley using X-ray attenuation tomography and cat-scan. Additional needs from the JIP are preserved core samples containing hydrates under representative conditions and the

characteristics of the cores (porosity, grain size distribution, mineral and fluid composition) to allow representative synthetic samples to be made for additional testing.

4. Mechanical properties. We need to understand the effect of dissociation on compaction and how hydrates will impact casing integrity. Existing sources of data or information are USGS – Stanford/USGS Menlo who have looked at compaction without dissociation. They can also look at compaction with dissociation as can Geomechanics International of Palo Alto. Additional needs from the JIP are preserved core samples containing hydrates under representative conditions and characteristics of the cores (porosity, grain size distribution, mineral and fluid composition) to allow representative synthetic samples to be made for additional testing.

5. Heat flow data. The JIP needs temperature profiles in first 1,000 m below seafloor. Existing sources of data or information are oil companies with operations in deepwater. Additional needs from the JIP are temperature versus depth in first 1,000 m, ocean bottom temperature and heat capacity-thermal diffusivity data.

In addition to the five critical areas described above, the breakout session identified the following areas where more data or information are needed. While these areas did not gather the votes to be identified as most important, they are nevertheless important. Innovative logging tools, such as the Raman spectroscopy (tested at Monterey Bay Aquarium Research Institute) could prove important. Other electrical measurements such as capacitance would be useful to the JIP. Chemical/physical effects on hydrate stability could also be important. Chemicals can inhibit or accelerate dissociation of gas hydrates.

Gas solubility in seawater at high pressure will be important data for the JIP. High pressure gas solubility data have not been published but some data have been measured at Texas A&M by Yuri Makogon.

5.2.3 Wellbore Stability

The participants in the breakout session discussed what is known about wellbore stability. Data from JNOC shows certain additives affect association and dissociation of hydrates while drilling.

JNOC has used chilled drilling mud to maintain hole integrity. JNOC eliminated riser due to seafloor instability issues.

LBNL has a reservoir simulator that includes geomechanics effects in the reservoir. GTI and Westport are separately studying the effects of additives on pure hydrates. The breakout session provided the following list of needs:

- Mechanical properties of sediments to allow structural design of well,
- How we relate laboratory data to wellbore stability,
- A valid wellbore stability model for hydrates,
- We will need tensile strength, Poisson's ratio, Young's modulus and shear field data for the model; and
- We should get data on synthetic samples first rather than consume valuable core material on difficult measurements.

5.3 Breakout Session M-2 on Modeling Seafloor Instability

This breakout session addressed seafloor instabilities, due to hydrates, on both a local and a large-scale basis. Items to be addressed were the ability of current models to predict hydrate presence and properties over time, the status of existing models, case histories of local instabilities and items to consider in selecting drill sites for Phase II of the JIP.

Key conclusions of this breakout session were as follows:

- There are few documented case histories of local seafloor instabilities.
- We know how to avoid areas of obvious hydrate concentrations that can be readily identified by faulting, mounds and vents.
- We know how to identify areas with a high probability of having no hydrates in the sediment, due to either no sources of gas and/or the physical features in the area.

- One big challenge is to predict the impact of disseminated hydrates that exist in low concentrations, in areas that currently "appear to be safe."

- There was consensus that in Phase II, the JIP should drill three test holes, in the same geologic area, to test locations of low, disseminated and high hydrate concentrations. (Several specific potential sites were identified.)

- Large-scale instabilities, due to hydrates, in the Gulf of Mexico are not a clearly proven phenomenon, and the attention of the JIP at this time should focus on "local" instabilities.

This breakout session focused on potential large-scale seafloor instabilities, and instabilities local to production facilities due to natural gas hydrates in the subsea sediments. Session topics included:

- Discussion of case histories of known local instabilities believed to be caused by dissociation of gas hydrates in subsea sediment,

- Determine current status of models, understanding of trigger mechanisms,

- Define data needed to constrain existing models and to develop improved models,

- Determine basis for selecting drill site in Phase 2 to provide the needed data,

- Define procedures for obtaining the needed data from cores and in-situ tests in Phase 2, and

- Discussion of case histories of large-scale seafloor instabilities.

The overriding purpose of this breakout session was as follows:

- Determine the state of current models and the case histories regarding seafloor instabilities,

- Develop ideas and plans as to how to move forward in the JIP's Phase II (approximately three wells currently planned), and

- Make connections with individuals/companies that may have proposals or specific plans on how to execute Phase II.

5.3.1 Jen-hwa Chen

Jen-hwa Chen explained that the primary task of the breakout session was to focus on "local" sediment instabilities, caused by gas hydrates. He suggested that Seafloor Instability for the JIP would involve a large-scale subsea landslide in which hydrates were the potential trigger. Also, a local instability (other then wellbore related) caused by production activities (subsea templates, pipelines, foundations etc.) would be a seafloor instability issue that interests the JIP. "Local" instability was deemed more relevant to the Gulf of Mexico and was discussed first. The implications of "large-scale" seafloor instabilities were discussed as the last item on the agenda.

5.3.2 Detailed Discussion

The participants first discussed case histories of known "local instabilities" that were believed to be caused by dissociation of gas hydrates in subsea sediment.

Jim Hooper reiterated the differentiation between "local" instabilities and "large-scale" instabilities, and stated that the focus of this discussion was on "local" instabilities caused by pipelines, facilities, templates, or foundations. The group was then asked to develop a list of know "case histories" of local instabilities.

Bush Hill Mound. Equipment that had been previously placed on the seafloor was gone one year after installation (Per Harry Roberts). It was hypothesized that the loss was due to hydrate build-up causing the equipment to float off

Mississippi Canyon 798. The University of Mississippi had a record in 1989 of an instability that was approximately 10-ft. All faults look exactly the same so there was no hint on seismic data as to the differences on the fault lines. This data from this example is public.

Caspian Sea. Alexei mentioned that the Caspian Sea could potentially provide a rich source of case histories of local instabilities. Exploration has been rough. Chevron should have some data on this. Larry mentioned an Atlas of Caspian Sea. Mostly pictures. A potential source is Ian Lerche/University of S.C.

The final conclusion of the group was that there is little documented evidence and few case histories of local instabilities. When asked if anyone in the group could mention one single instance of a local instability causing a problem on the seafloor, none could be identified.

The next topic concerned the "Status of Current Models". There was broad discussion over what type of models we were taking about. What questions were we looking to answer seemed to be the driver for the discussion. Were we trying to predict where hydrates would occur, in what quantities, in what concentrations or were we trying to model the impact of a local seafloor instability with an "engineering model", or were we trying to do something in between these two extremes?

It was concluded after some discussion that where we have specific data, and a clear problem to address we can do some reasonable modeling work. Models to study the impact of "local instabilities" are relatively easy, and can be/should be tested by the JIP. Most agreed that these "engineering models" to study very specific mechanical issues were relatively easy to develop and pursue. In the Gulf of Mexico we can predict safe/non-hydrate areas with high predictability (due to lack of faults, mounds and surface/subsurface features).

The group began a discussion of what were the gaps with existing models to study local instabilities. The discussion was very animated and strongly opinionated, but it soon became apparent that the discussion lacked focus because there was no clear or common understanding on 1) what types of models were we referring to, 2) what was the "problem" that we were trying to solve with the models, and 3) the models would be by themselves to make prediction or used in conjunction with other ground truth data.

There was agreement that we needed to reach some common ground on what type of model we were discussing and what was the problem to be addressed. After much discussion the following was concluded:

In the case of known areas of hydrate concentrations in the Gulf of Mexico, these areas are easily detected via seismic and/or surface features. We generally have a high confidence in our ability to detect hydrates and the adequacy of existing modeling is good. In areas of low to no hydrate occurrence, these areas can also be determined relatively easily due to lack of surface/subsurface features and/or lack of a gas source. Our ability to detect these areas of no gas hydrate occurrence is relatively high, although our ability to model them is poor due to uncertainties in input. Our biggest challenge is dealing with areas that are apparently safe but could have undetected gas hydrate deposits. Confidence in our ability to detect hydrates (and their concentrations) was determined to be "uncertain" and our modeling adequacy as "poor."

It was noted that the above "situations" represented a continuum and that these were three points on that continuum. This discussion resulted in a statement that attempted to address the question of "what is the problem the JIP is trying to solve" with models.

The key issue is how to make sure that apparently safe locations (that have potentially disseminated hydrates), . . . will in fact prove to be safe over time and related activities.

All agreed that this was the key problem that needed to be addressed with models.

The breakout session participants next listed some of the gaps in knowledge affecting seafloor stability modeling. These gaps are as follows:

- Mechanical/Thermal prediction capabilities are missing in many of our models,
- Current Seismic Surveys do not give us the capability to accurately predict hydrate content,
- Seismic surveys need to be calibrated against models to verify hydrate content and properties,
- Ability to predict the location of hydrates is rather primitive,
- Most models assume homogeneity,
- Seismic, thermal, and electrical models are not very sophisticated, and
- Our ability to predict the concentration of disseminated hydrates is very poor.

An important clarification: the discussion on modeling should be viewed in the perspective that for a given location, models would most likely be used in conjunction with other data (boreholes, seismic data, etc.,) and not as tools to make prediction by themselves.

The discussion above focused on the case of "disseminated hydrates" as being the critical area. There was a general observation, that while a lot of data has been collected by industry, there was a broad lack of data from 10' to 1500' below the mud line.

The following data were identified as generally missing:

- Temperature data,
- Heat flow data (for thermal gradients),
- Pore pressure data,
- Pore fluids composition,
- Composition of gases,
- Permeability data,
- Mechanical properties (sheer strength and compressibility),
- Sediment composition, age, sedimentation rate,
- Salt definition,
- High resolution 3-D seismic plus logs,
- Well data,
- In-situ data gathered over time after coring to monitor any changes, and
- In hydrate sediment composition/distribution or strength.

It was generally agreed that to significantly improve existing models in areas of disseminated hydrates that a "maximum suite" of data gathering should be undertaken. It was also noted that a key issue would be to calibrate the core data with remote sensing data (such as logs and seismic) so that confidence could be developed that physical properties could be adequately predicted without the cores.

The group then shifted gears and asked the question "what types of new data collection techniques might be used to collect pertinent information on hydrates?" The following two approaches were advocated.

5.3.3 Jim Hooper

Jim Hooper advised that Fugro is working on an "optical cone." This is a standard cone pentrometer that illuminates the sediment as it passes through, has 100-300 depth range, visually sees hydrates, can measure resistivity, pore pressure and temperature.

5.3.4 Mike Williamson

Mike Williamson advocated the use of passive seismic tomography. This uses latent seismic activity in the earth to produce energy sources to measure seismic rock properties, such as Poisson's ratio and S&P wave data. A sensor could be installed in-situ and these properties measured over time to sense changes in hydrate bearing sediments.

At the conclusion of this discussion on data needs, there was a strong consensus amongst the group that the JIP had **a tremendous opportunity to place sensors in-situ and measure the properties over time.** Everyone agreed that this was a real gap in our knowledge; how do hydrate sediments change over time. All agreed that the JIP could add significantly to the body of knowledge if this approach were taken.

On Friday morning, May 10, 2002, the participants in the Breakout Session were asked what site they would select for the JIP to drill its currently planned three wells in. A discussion ensued around the fact that inherent in anyone's selection of a site, would be a "hypothesis" in their own mind that they were trying to prove through the planned well sites. Therefore each participant was asked to describe 1) a site and 2) the "hypothesis" they were trying to prove by selecting that site.

5.3.5 Alexie Milkov (Texas A&M) Site - MC 852, 853 -- known and characterized hydrate location.

His hypothesis is that gas hydrate concentrations within the first 6 meters do not change.

5.3.6 Brandon Dugan (Penn State) and Ras Pandey (Naval Research Lab) Site - MC 852, 853

Their hypothesis is that gas hydrate and gas flow adversely affects the flow and strength properties of the sediments. Need to test the 3 types of locations (high, moderate and low concentration points).

5.3.7 Doug Turner (Colorado School of Mines) Site - MC 852, 853.

His hypothesis is to concentrate on the intermediate (disseminated hydrates) more than the "end members" of high and low concentration sites.

5.3.8 Larry Cathles (Cornell University) Site - Jolliet Area.

His rationale is that this site has the longest history of data collection, thermogenic and biogenic hydrates. Well 1 in Hydrate Mound had various hydrate concentrations and volumes that decreased with depth. Well 2, in the area of Jolliet Platform, should be used to determine biogenic hydrates 100' below ML. Well 3 can be adjacent to Bush Hill Mound to test if there is any leakage into surrounding sediments.

5.3.9 Alan Lowrie (Consultant) Site - MC 798.

His hypothesis is to test the impact of complex stratigraphy on hydrate concentrations.

5.3.10 Doug Turner (Colorado School of Mines)

He would pick a site to look for both high flux and low flux hydrate areas, and would look at the geologic complexity. Try to test areas where the geologic complexity can be characterized with the boreholes. His hypothesis would be to review the structural complexity in an area and its relationship to long-term measurements, as well as its relation to hydrate rate of flux.

5.3.11 Michael Williamson (Williamson & Associates)

He would choose a site where 3 closely spaced holes can be drilled, so we have similar situations geologically, but test a high hydrate, low hydrate and moderate hydrate location. His hypothesis is that response to morphological changes due to flux rate is key.

5.3.12 Dennis Kurnerth (INEEL)

He would choose a site with wells to test 3 ranges of hydrates, well characterized sites (all Jolliet/Bush Hill), add some additional data (new data). His hypothesis was that if you combine a wide range of existing and new data, we will more accurately be able to characterize the sites.

After each individual presented his site selection and hypothesis, the others on the team were given the opportunity to ask questions for clarification and understanding to ensure they understood the rationale presented. At the end of the discussion, the well sites chosen in order of preference were MC 852, 853, MC 798, Bush Hill, and GC 184, 185.

A consensus grew on the criteria for site selection. This consensus included the following:

- Test three ranges of hydrate concentrations (high, low and disseminated),
- Drill in the same geologic area (to minimize the issue of geologic complexity),
- Select an area with existing data characterization,
- Gather additional new data and test potential new data gathering tools (logs, seismic, etc.), and
- Monitor the site on an ongoing basis following coring.

The group was asked to look at the issue of "large-scale" instabilities caused potentially by hydrates and comment on the relevance of this to the work of the JIP. Large-scale instabilities caused directly by hydrates in the Gulf of Mexico are not a clearly proven phenomenon. There are numerous slump features, but the role of hydrates as a trigger in these areas is uncertain. There are also numerous mud mounts. In general, industry has been able to identify mud mounts and stay clear of them. The more uncertain issue is to what extent could activities in a given area (as an example, down slope from a mound) potentially precipitate a "large-scale" event. All agreed that the first priority should be the prevention of "local instabilities", but also noted that there are obvious synergies between the science involved in local and large-scale instabilities.

The unknown here is that hydrates are dynamic. There is the potential to trigger mudslides. We've not looked at this in the past as a dynamic problem. This is an open issue, but is not the highest priority for the JIP currently.

The following observations were made regarding models for "large-scale" instabilities:

- Models for large-scale instabilities are very primitive,
- Data will come out of the JIP that will provide information, and

- This is another rationale for long-term, ongoing data collection.

The group concluded the following regarding large-scale instabilities and their relevance to the JIP:

- There are known slumps in the Gulf of Mexico in the hydrate stability zone.
- Hydrates as a trigger are not publicly implicated in any of these slumps.
- We should give priority to "local instabilities."
- But there are obvious synergies between "local" and "large-scale" instabilities.

5.4 Breakout Session M-3 on Seismic Attributes and Verification of Seismic Analysis

This breakout session addressed the role of seismic data in geoscience and reservoir modeling to better predict the characteristics of hydrate bearing sediments. Specific areas of focus included acquisition and processing requirements for seismic data, prioritization of seismic data requirements and procedures to allow calibration of seismic data to cores collected in Phase II of the JIP.

Key conclusions of this breakout session were as follows:

- Rock properties modeling and its impact on seismic acquisition and processing were identified as a major unknown regarding the ability of seismic to define the characteristics of hydrate sediments.
- Several model-based processing issues and the role of multi-component data were identified as major unknowns for seismic acquisition and processing required to model hydrates and their distribution.
- Three major unknowns were identified regarding seismic data requirements to develop geoscience and reservoir models. These were 1) how to extract rock properties from seismic data, 2) how to tie seismic data to the geologic model and 3) how to marry rock properties with reservoir properties. Several potential approaches were identified to close these gaps.

- Selecting a proper drill site, in a high hydrate concentration area, will be critical to enhance the calibration of seismic data to new core data. Key unknowns are a list of criteria to select a proper drill site. Several potential approaches to developing those criteria were identified.

This breakout session considered the use of seismic information in geoscience and reservoir modeling of sediments that contain natural gas hydrates. Session topics included the following:

- Identify the characteristics of seismic data that can be used to define sedimentary units containing massive gas hydrates deposits,

- Discuss the acquisition and processing requirements for seismic data that will be the most valuable in modeling hydrates formation and distribution,

- Determine and prioritize seismic data requirements that, in combination with information and samples obtaining by this JIP, will allow the development of state-of-the-art geoscience and reservoir models, and

- Define procedure to allow the calibration of seismic data and models of buried gas hydrates in the Gulf of Mexico with the results from core collection test sites in Phase 2.

5.4.1 Detailed Discussion

Roger Entralgo, Oceaneering. His company is doing final sea trials on their AUV, Automated Underwater Vehicle. They have intervention class vessels. Different vessels are: Cable deployment vessels and cable burial vessels, which have burial assessment equipment, low-tension cable plough, plough system, Phoenix ROV System. Tensioner system limitation is about 10 k feet. Cable burial - low tension has plowed 1500 k meters. World's largest ROV systems in the world and they operate 85% in the Gulf of Mexico. Time lapse is useful in imaging gas hydrates. Time can be useful in gas floor for modeling. Able to monitor zone while drilling, take snapshots prior, while, and during drilling. With the AUV one is able to learn what happens during the drilling process.

Masao Hayashi, Japan National Oil Corporation. Masao is interested in the vertical scale of time-lapse seismic data. Most geophysicists in Japan focus on the deep zones when processing and analyzing seismic data. In a conventional situation, geologists try to investigate deep formations to find oil and gas. Gas hydrate is a new issue and must be dealt with differently. He showed the seismic parameters for the Nankai Trough near Honshu Island. The following information was used to shoot seismic that was successful in delineating the upper limit for the hydrate zone in the Nankai Trough.

- Energy source Sleeve Gun
- Volume 1,330 ci
- Number of guns 20-tunEd array
- Depth of guns 4 meters
- Streamer digital
- Length 3,000 meters
- Number of channels 474

Dave Weinberg. He showed recent lab experiments with THF (tetrahydrofuran), water, and an unconsolidated sand system to simulate gas hydrate freezing and melting. THF forms hydrate with water. Pressure and saturation waves were monitored during formation and dissolution of THF hydrate (no gas phase) and thermal cycling response. One has to take a lot of different data to see what is going on. The experiment lasted 650 hours.

Dick Fillon, Earth Studies Associates. Their concept is that they use high amplitudes to show that gas is present in the system. He noted that elevated temperatures are sometimes present on the bottom of the seafloor. If gas hydrates outcrop on the shelf, one will see the outcrop strata and venting of gas along the seafloor, visible in the water column. We see that as part of an older collection system, probably moving laterally. We have seen a large circular hole in the formation in the bottom of the seafloor. This could be associated with a massive dissolution of hydrates into gas. It could be a barrel for the smoking "hydrate gun" for dispersing massive amounts of methane into the atmosphere, producing climate change in the past.

Tony George, C & C Technologies. He showed his presentation on his computer. His presentation was non-publishable, proprietary oil company data. He showed some stratigraphic charts as well as selected slides from his OTC presentation on recent AUV results. The AUV goes to 3,000 meters depths. The technology allows decisions on pipeline routing and drill sites. A key feature is collection of slope gradients and other details of the ocean floor. Even when we drill it, we don't know if it's hydrate. All the data were collected from data reading from the AUV.

Topic 1. Identify the characteristics of seismic data that can be used to define sedimentary units containing massive gas hydrates deposits.

5.4.2 Summary

What is Known?

- Frequency content.
- Acquisition geometry.
- Energy source.
- High amplitude event.
- Higher velocity.
- Acoustical void zones (hi freq 2-8 mhtz).
- BSR-Open for debate (data gathered on boats is better).
- Most of existing data is P-wave.
- Modern data is useful from last year.
- Suspect that processing parameters are unique.
- Suspect 2 millisecond enhances the processing of data.
- Large offset data is better.

What is Unknown?

- Validity of zero offset.
- Shear wave properties.
- Permanent vs. nonpermanent installation of receivers.

- Time-lapse effects on seismic properties.
- 2D vs. 3D vs. OBC.
- Single source receiver array.
- Effect of gas hydrate geomodels on acquisitions and processing of geophysical data.
- Density – Rock properties and its impact on seismic acquisition and processing.
- Effect of attenuation.
- AVO – Shallow gas hydrate deposits.
- Effect of energy source on seismic data quality.
- Scaling issues of going from wellbore to seismic data.
- Impact of Seismic while Drilling (SWD).

Several of these properties can be combined into one large unknown that can be described as "Rock properties modeling and its impact on seismic acquisition and processing."

What are the critical approaches to close the gap?

- Improved rock properties modeling to determine how to improve seismic acquisition and processing.
- Gather multi-component seismic data – (OBC, Sea bottom sources).
- Improved forward seismic modeling using petro-acoustical parameters.
- Collect more seafloor and subsea temperature data.
- Possible use of SWD.
- More application of seismic facies analysis.

Topic 2. Discuss the acquisition and processing requirements for seismic data that will be the most valuable in modeling hydrates formation and distribution.

What is Known?

- Preference – Point source array monitoring receivers, high-resolution 3D resolution.
- Focus on shallow sediment is inadequate.
- Acquisition parameters and survey design not optimized for shallow sediments.
- Need long offset data to discriminate rock properties.
- Preserve true relative amplitude.

What is Unknown?

- Adequate processing parameters.
- Migration/velocity of seismic data.
- Effects of water properties on seismic parameters.
- Effects of loop currents.
- Usefulness of current state of data.
- The optimum acquisition data – sampling.
- Role of OBC – Do we know how to process?
- Don't know how to integrate geo tech data and geo physical data.
- Geo modeling – link to acquisition and processing of data.

What are the critical approaches to close the gap?

- Correct modeling.
- Analyze several deposits (over different GH areas).
- Adequate well log data for gas hydrates.
- Investigate existing OBC data.
- Find out the distribution of seismic data around known OBC data.

- Try to adapt to some slimmer hybrid system for cabling data; perhaps adapt electrical to optical convergence technology to get lighter cables.
- New OBC grid going in by WesternGeco on two mile by two mile grid over much of the Gulf of Mexico.
- Acoustical ultrasonics to ID physical properties in heterogeneous materials.
- Utilize existing data currently being shot.
- Need "correct" models (effective medium theory, e.g.).
- Analyze detail of several known deposits.
- Good well-log data.
- Compare site survey data with conventional 3D for rock properties.
- Investigate existing OBC data.
- Reprocess existing seismic data over known GH deposits.
- Influence data collection from new OBC grid being laid in the Gulf of Mexico.
- Role of time lapse multi-component.
- Investigate existing data base over known GH deposit.

Topic 3. Determine seismic data requirements to develop geoscience and reservoir models.

What is Known?

- Modeling.
- Acoustical Properties of gas hydrates.
- Rock Porosity.
- Density.
- Saturation.
- Distribution of Hydrates in Sediments.
- Cementing Properties.

- Relative Permeabilities.
- Thermal Properties (Temp and Heat Conductivity).
- Geometry and Morphology.
- Bulk and Permeability – Degree of Heterogeneity.
- Host Rock Properties.
- Rock Mechanics.
- Level of Consolidation.
- Pressure Regime.
- Well Logs as an Aid to Modeling and Inversion.
- In-Situ State of Stress.
- Detailed Stratigraphic Framework.

What is Unknown?

- Don't know how to extract known from existing seismic data?
- How to tie seismic to geological model?
- Which models are needed?
- Static reservoir model (look at 2000 conference, Nancy Burke, at Chevron).
- Utility of static reservoir model.
- Marry rock mechanical properties with reservoir models.
- Utility of conventional modeling tools.

What are the critical approaches to close the gap?

- Full waveform inversion of multi-component seismic data.
- Tie of seismic to bore hole data.
- Multi-component data.
- Record multi-component VSP.

- Laboratory approaches to extract some attributes information of extract gas hydrates.
- VSPs.
- Detail stratigraphic interpretation.
- Log data (synthetic seismogram).
- Core analysis.
- Temperature profiles, pressure, transients, detailed VS/VP.
- Acquiring Multi-component data.
- Bio-strat analysis.
- Hydrate structure during various production.

Topic 4. Define procedure to allow the calibration of seismic data and models of buried gas hydrates in the Gulf of Mexico with the results from core collection test sites in Phase 2.

What is Known?

- Analyze existing areas and data available.
- Define geography of existing data.
- Reprocess existing data.
- Acquire permanent sensor data before, during, and post drilling.
- Map of known Gulf of Mexico deposits.
- Some based line surveys exist before, during, and post drilling.

What is Unknown?

- What is the optimal candidate drill site?
- Don't have procedures for measuring cores.
- The economics and logistics.
- Factors for down scaling.

What are the critical approaches to close the gap?

- Use Venn diagram to create short list.
- Timing, when data is available, the existing data.
- Utilize existing data (seismic, bore holes, etc.)
- Use Mike's known maps of hydrate deposits for critical data.
- Flush out Mike's list of criteria for selection of drill site.
- Create sub-committee to determine where to drill for the known hydrate location.

JIP DATA AVAILABILITY (Information that can be shared with the JIP)

1. Mike Smith, MMS, Regional Operations Geologist, Deepwater Gulf of Mexico

michael.smith@mms.gov

504-736-2500

Description of Data	Format of Data
Well logs + data for offset wells (over 2 yrs old)	digital after 1995 but only LWD for shallow sections

Shallow hazards reports (if released) can request operator to release proprietary

3D exploration seismic.

Will work with Jesse Hunt and others to provide map of known surface hydrates.

2. Tony George, C&C Technologies, Geosciences Manager

Tony.george@cctechnol.com

337-261-0660

Description of Data

AUV data from MMS sponsored Continental Shelf and associated "Physical Seafloor Characterization of Selected Drill Sites." 3 block studies. All areas greater than 1.000 meters.

Format of Data

X, Y, Z Bathymetry. Data of 3-meter bins. Frequency modulated 2-8 kHz data in SEGY or XTF. 120 kHz Sidescan Sonar Data.

3. Dave Weinberg, Fellow, INEEL

weinbe@inel.gov

208-526-4274

Description of Data

Pressure and S-wave monitoring during formation and dissolution of THF hydrate (no gas phase) and thermal cycling response.

Format of Data

Publications.

4. Nader Dutta, Chief Geoscientist, WesternGeco

ndutta@houston.westerngeco.slb.com

713-824-6935

Description of Data

Seismic data over known GH area.

Format of Data

SEGY

APPENDIX A

ATTENDEES AT THE DATA COLLECTION WORKSHOP

Raj Bishnoi, University of Calgary
Ben Bloys, ChevronTexaco
James M Brooks, TDI-Brooks International Inc.
William Bryant,
Lawrence M. Cathles, Cornell University
Eric Cauquil, TOTALFINAELF
Jen-hwa Chen, ChevronTexaco
Richard B. Coffin, NRL
Michael P. Curtis, Halliburton
Gordon Deppe, Nexant, Inc.
Gary Dixon, Gas Technology Institute
Ashley Donaldson, Halliburton
Earl Doyle, Ocean Studies Board
William B. Durham, Lawrence Livermore National Lab
Nader Dutta, WesternGeco
Jack P. Dvorkin, Stanford and Rock Solid Images
Peter Eick, CONOCO
Joseph F. Gettrust, Naval Research Laboratory
Ken E. Gray, University of Texas at Austin
William J. Gwilliam, US DOE/NETL
Bob Hardage, Bureau of Economic Geology
Patrick E. Hart, USGS
George He,
Stephen A. Holditch, Schlumberger
James Holste, Texas A&M University
W. E. Hottman, Halliburton Energy Services
Jesse Hunt, Jr., DOI/Minerals Management Service
Deborah R. Hutchinson, USGS
Priyank Jaiswal, Rice
Arthur Johnson, Hydrate Energy International
Emrys Jones, ChevronTexaco
Arnis Judzis, TerraTek, Salt Lake City, Utah
Bayram Kalpakci, Westport Technology Center
Aftab Khokhar, Westport Technology Center
Stephen H. Kirby, US Geological Survey
Robert Kleinberg, Schlumberger
Jack J. Kolle, Tempress Technologies Inc.
Jan Krason, Geo Explorers International
Dennis Kunerth, INEEL
Karl R. Lang, Hart Publications
Tom Lorenson, USGS
Allen Lowrie, Consultant

Devinder - Mahajan, Brookhaven National Laboratory
Yuri F. Makogon, Texas A&M University
Subhashis Mallick, WesternGeco
Dan McConnell, Fugro GeoServices, Inc.
David McCormick, Schlumberger-Doll Research
Thomas M. McGee, University of Mississippi
Alexei V. Milkov, GERG, Texas A&M University
Pierre Montaud, TOTALFINAELF
George Moridis, LBNL
Tom Morz, DOE NETL
Lecia Muller, WesternGeco
Jillian N. Nimblett, Georgia Institute of Technology
Sheila Noeth, Schlumberger
Lewis Norman, Halliburton Energy Services
Koji Ochiai, Japan National Oil Corporation
William Parrish, Phillips Petroleum Company
Charles K. Paull, Monterey Bay Aquarium Research
Tommy J. Phelps, ORNL
Dick Plumb, Schlumberger
Frank R. Rack, Joint Oceanographic Institute
Claudia J. Rawn, Oak Ridge National Laboratory
Harry H. Roberts, Coastal Studies Institute
Adam J. Rondinone, Oak Ridge National Laboratory
William W. Sager, Texas A&M University
Iraj A. Salehi, Gas Technology Institute (GTI)
Roger Sassen, Texas A&M University
Martin Schoell, Isotech Laboratories, Inc.
James P. Schumacher, ChevronTexaco Deepwater Drilling
Yugdutt Sharma,
Keshwa Shukla, Westport Technology Center
Richard Sigal, Anadarko Petroleum Corporation
Alwarappa Sivaraman, Gas Technology Institute (GTI)
Dendy Sloan, Center for Hydrate Research
Michael A. Smith, Minerals Management Service
Richard Solem, Scripp's Institution of Oceano
Gene W. Sparkman, Energy Research Clearing House
Sivakumar Subramanian, ChevronTexaco EPTC
Brad Tomer, DOE NETL
Peter Trabant,
Douglas Turner, Colorado School of Mines
Randal W. Utech, WesternGeco
William (Bill) F. Waite, U.S. Geological Survey
Joel D. Walls, Rock Solid Images
Dave Weinberg, INEEL
Brett L. Wendt, CONOCO
Olivia R. West, Oak Ridge National Laboratory

Tom E. Williams, Marurer Technology
Michael E. Williamson, Williamson & Associates, Inc.
William J. Winters, U.S. Geological Survey
Warren Wood, Naval Research Laboratory
Janet Yun, Wesleyan University

APPENDIX B

ATTENDEES AT THE WORKSHOPS ON DRILLING, CORING, AND CORE ANALYSIS AND MODELING, MEASUREMENTS, AND SENSORS

First Name	Mid	Last Nname	Affiliation	Bus Phone	emailaddr
Jim	T	Aumann	Aumann & Associates, Inc.	801-631-2874	aumann.and.assoc@worldnet.att.net
Dennis		Bateman	Halliburton	713-937-3198	
Ben		Bloys	ChevronTexaco	281-230-2968	ben.bloys@chevrontexaco.com
Jacques	G	Bourque	Schlumberger	281 285 1263	bourque1@slb.com
Robin	C	Buchannon	Center for Marine Resources and Environmental Technology	662-915-7320	rcb@mmri.olemiss.edu
Jon		Burger	Westport Technology Center	713-479-8407	Jon.Burger@Westport1.com
Lawrence	M	Cathles	Cornell University	607-255-2844	cathles@geology.cornell.edu
Jen-hwa		Chen	ChevronTexaco	281-230-2787	jenc@chevrontexaco.com
Timothy	S	Collett	USGS	303-236-5731	tcollett@usgs.gov
Mark	E	Delwiche	INEEL/BBWI	(208) 526-1870	mde1@inel.gov
Brandon	E	Dugan	Penn State University	814-863-9663	dugan@geosc.psu.edu
Nader		Dutta	WesternGeco	713-689-6370	ndutta@houston.westerngeco.slb.com
Peter	M	Eick	Conoco	281-293-3387	peter.eick@conoco.com
Roger	D	Entralgo	Oceaneering	832-467-7849	rentralgo@oie.oceaneering.com
Richard	H	Fillon	Earth Studies Associates	(504) 394-0797	fillorh@bellsouth.net
Benjamin	P	Flower	University of South Florida	727-553-3986	bflower@marine.usf.edu
Barry	M	Freifeld	Lawrence Berkeley National Lab	510 486-4381	bmfreifeld@lbl.gov
Robert "Tony"	A. A	George	C & C Technologies, Inc.	337-261-0660	tony.george@cctechnol.com
Richard		Graham	Williamson & Associates, Inc.	(206) 285-8273	richardg@wassoc.com
Ken		Gray	University of Texas at Austin		ken_gray@mail.utexas.edu
P. R.		Hariharan	Hydril - SMDC	281-985-3339	
Bill		Hauser	MMS	703 787-1613	william.hauser@mms.gov
Masao		Hayashi	Japan National Oil Corporation	81-43-276-9569	hayasi-m@jnoc.go.jp
DENDANI		Hedi	TOTALFINAELF	33-1-4135-8438	hedi.dendani@totalfinaelf.com
Stephen	A	Holditch	Schlumberger	979-764-1122	sholditch@slb.com
James	C	Holste	Texas A&M University	979-845-3384	j-holste@tamu.edu
James	R	Hooper	Fugro-McClelland Marine Geosciences, Inc.	713-369-5574	JHooper@Fugro.com
Gary	D	Humphrey	Fugro-McClelland Marine Geosciences, Inc.	(713) 369-5579	ghumphrey@fugro.com
Jesse	L	Hunt, Jr.	Minerals Management Service	504-736-2440	jesse.hunt@mms.gov
Yuichiro		Ichikawa	Japan National Oil Corporation	81-43-276-9538	yichi@jdc.co.jp
Arthur	H	Johnson	Hydrate Energy Int'l	504-464-6208	artjohnson51@hotmail.com

First Name	Mid	Last Nname	Affiliation	Bus Phone	emailaddr
William	B	Jonasson	Ocean Drilling Program	979-845-2024	Jonasson@odpemail.tamu.edu
Emrys	H	Jones	ChevronTexaco	281 596-2269	ejones@chevrontexaco.com
Bradley	D	Julson	Ocean Drilling Program	979-845-5716	julson@odpemail.tamu.edu
BAYRAM		KALPAKCI	Westport Technology Center Intl,	(713) 479-8439	bayram.kalpakci@westport1.com
MASAYUKI		KAWASAKI	JAPAN NATIONAL OIL CORPORATION	043-276-9538	kawask-m@jnoc.go.jp
Aftab		Khokhar	Westport Technology Center Intl,	713 479 8508	aftab.khokhar@westport1.com
Doug		Kinsella	Corion Diamond Products	780-955 8929	dougk@coriondiamond.com
Stephen	H	Kirby	USGS	650 329 4847	skirby@usgs.gov
Robert		Kleinberg	Schlumberger	203-431-5410	kleinberg@slb.com
Pushpendra		Kumar	Center for Hydrate Research	303-273-3212	kpushpendra@hotmail.com
Dennis	C	Kunerth	INEEL	208-526-0103	dck2@inel.gov
Jonathan	T	Kwan	Anadarko Petroleum Corp	832 636-1388	jonathan_kwan@anadarko.com
Bill	V	Liddell	Anadarko Petroleum Corp	832-636-1695	bill_liddell@anadarko.com
Bill		Loth	Halliburton Energy Services	281-575-5289	bil.loth@halliburton.com
Allen		Lowrie	Consultant	228-688-4443	
J. Bryan		Maggard	Texas A&M University	979-845-0592	
Devinder	-	Mahajan	Brookhaven National Laboratory	(631) 344-4985	dmahajan@bnl.gov
John		Matson	Halliburton Energy Services	281-575-4547	john.matson@halliburton.com
David		McCormick	Schlumberger-Doll Research	203-431-5524	dmccormick@slb.com
Alexei	V	Milkov	GERG/TAMU	979-862-2323 ext 117	milkov@tamu.edu
Lecia	K	Muller	WesternGeco	713-689-6209	lmuller@houston.westerngeco.slb.com
Narender	R	Nanchary	UH	7137434306	nanchary@rediffmail.com
Lewis		Norman	Halliburton Energy Services	580-251-3865	lewis.norman@halliburton.com
Koji		Ochiai	Japan National Oil Corporation	+81-43-276-9243	ochiai-k@jnoc.go.jp
Toshiharu		Okui	Japan National Oil Corporation	+81-43-276-9289	okui-t@jnoc.go.jp
Ras	B	Pandey	Naval Research Laboratory	228 688 5480	ras.pandey@usm.edu
William	R	Parrish	Phillips Petroleum Company	918-661-9651	wrp@ppco.com
Tommy	J	Phelps	Oak Ridge National Lab.	(865)574-7290	phelpstj@ornl.gov
Sven	J	Plasman	Fugro-McClelland Marine Geosciences, Inc.	(713) 369-5619	splasman@fugro.com
Dan		Postler	Devon Energy	713.286.5964	dan.postler@dvn.com
Eric	C	Potter	Bureau of Economic Geology, The University of TX at Austin	512-471-1254	eric.potter@beg.utexas.edu
Frank	R	Rack	Joint Oceanographic Institutions	202-939-1624	frack@joiscience.org
Joseph	B	Renk III	U.S. DOE/NETL	412-386-6406	joseph.renk@netl.doe.gov
John		Rogers	DOE/NETL/SCNG	304-285-4880	john.rogers@netl.doe.gov
Carolyn		Ruppel	Georgia Tech	404-894-0231	cdr@piedmont.eas.gatech.edu
Derryl	G	Schroeder	Ocean Drilling Program - Texas A&M	979 845 8481	derryls@tamu.edu

First Name	Mid	Last Nname	Affiliation	Bus Phone	emailaddr
james	p	schumacher	chevrontexaco	713-432-6066	jamesschumacher@chevrontexaco.com
Terry		Shawchuk	Corion Diamond Products	403-261 8089	terrys@coriondiamond.com
Brent	L	Shoemaker	Transocean Sedco Forex	979 696 7955	bshoemaker@college-station.deepwater.com
Keshawa	P	Shukla	Westport Technology Center International	713-479-8427	keshawa.shukla@westport1.com
Alwarappa		Sivaraman	Gas Technology Institute (GTI)	847-768-0998	alwarappa.sivaraman@gastechnology.org
Dendy		Sloan	Center for Hydrate Research/ Colorado School of Mines	303-273-3723	esloan@mines.edu
MICHAEL	A	SMITH	MMS	504-736-2500	MICHAEL.SMITH@MMS.GOV
Sivakumar		Subramanian	ChevronTexaco	281-596-2246	sisu@chevrontexaco.com
Douglas	J	Turner	Center for Hydrate Research/ Colorado School of Mines	303-273-3212	djturner@mines.edu
Randal	W	Utech	WesternGeco	713-689-6450	
Dave		Weinberg	INEEL	208-526-4274	weinbe@inel.gov
Michael		Williamson	Williamson & Associates, Inc.	(206) 285-8273	mikew@wassoc.com
Bill	J	Winters	USGS	508-457-2358	bwinters@usgs.gov
Gary Yu		Yu	TotalFinaElf E&P USA Inc.	713-647-3453	gary.yu@totalfinaelf.com