INSTITUT FRANCAIS DU PETROLE

Direction de recherche
"Exploitation en Mer"

RE 20 ChS/JN Note 26

19 May 1989

SEVENTH MEETING OF THE JOIDES TECHNOLOGY AND ENGINEERING DEVELOPMENT COMMITTEE (TEDCOM)

College Station, Texas
27-28 April 1989

Ch. SPARKS

EXECUTIVE SUMMARY

1. The two day meeting had the following prime objectives:

   - assess results of the first engineering leg, and hence orientate future developments

   - formulate the TEDCOM response to the O.D.P. Long Range Plan.

2. A new wording for the TEDCOM mandate was agreed upon, in tune with the TEDCOM mode of operation. It was transmitted to PCOM for approval.

   (See Appendix B)

3. Following discussion of the engineering leg 124E, four recommendations were made:

   - The DCS should be retested as soon as possible in optimum conditions, with a cased hole, at a site already known to have basement at an acceptable level. Water depth should preferably be close to 1 500 m. This should only be increased if required by site considerations.

     (TEDCOM recommendation 89/1)

   - A TEDCOM subcommittee, composed of the following members, should be created to advise TAMU on mining drilling: W. Svendsen (coordinator), K. Millheim, F. Schuh, J. Coombs, P. Wickland. Their associated travel expenses should be paid by J.O.I.

     (TEDCOM recommendation 89/2)

   - A. SKINNER of B.G.S., a consultant with intimate knowledge of the D.C.S. systems of the "Pholas" and the "Bucentaur" should be encouraged to participate in the above sub-committee. His travel expenses should be paid by J.O.I.

     (TEDCOM recommandation 89/3)

- TAMU should study ways of modifying the DCS, so as to immobilize the lower end of the API string during all phases of DCS operation.

(TEDCOM recommendation 89/4)

4. During discussion of the development of the Navidrill, it was suggested that ways be studied of dissociating the weight on bit from the rotational speed, by using a sand line to reduce W.O.B.

5. The TEDCOM response to the Long Range Plan was formulated and immediately hand carried to the PCOM meeting in Oslo.

(See Appendix D)

6. Hard rock core orientation for Leg 130. This was discussed at the request of R. Moberly. The TEDCOM concurred with TAMU that no suitable (acceptable) system was commercially available today. An Arco system that suppressed the natural magnetism of the cores was considered unsuitable.

7. The TEDCOM considers that TAMU is spreading its research effort too wide. In particular high temperature drilling research, which is already being undertaken by Los Alamos and Sandia, should not be duplicated by TAMU.

8. TEDCOM members were alarmed at the frequency at which BHAs have been shot off in recent months.

9. The TEDCOM concurred with TAMU that the cleaning of hole 504B should not be combined with an engineering leg.

10. The TEDCOM recommended that O.D.P. should acquire, for the JOIDES RESOLUTION, an unconfined compression tester for hard rock, to give immediate knowledge of compressive strengths, to allow improved drilling and coring.

(TEDCOM recommendation 89/5)

11. SMP will look at ways of acquiring data from cores to give indications on swelling that could lead to stuck pipe.

12. Next meeting
Probably England in Jan. 1990 (to coincide with land test of DCS). Date and place to be confirmed.

Charles SPARKS
10 MAY 1989

LIST OF ATTENDEES

TEDCOM Members

Charles SPARKS, Chairman	IFP
Jean BONASSE-GAHOT	ELF
Martin CHENEVERT	Univ. Texas, Austin
Keith MANCHESTER	CGS/BIO
Archie McLERRAN	Consultant
Keith MILLHEIM	AMOCO
Heinrich RISCHMULLER	KTB
Frank SCHUH	Drilling Tech. Inc.
Harald STRAND	Norsk Hydro.
Walter SVENDSEN	Consultant

TEDCOM Replacements

John COOMBS (for B. COTTEN)	CHEVRON
Junzo KASAHARA (for H. FUJIMOTO)	Univ. Tokyo

TEDCOM Liaisons

Joel WATKINS (for G. BRASS)	PCOM
Barry HARDING	TAMU
Al. SUTHERLAND	NSF
Paul WORTHINGTON	BP/DMP

Permanent Observers

Willie BRANDT	SEDCO
Percy WICKLUND	DOSECC

Guests

Kate MORAN	BIO	SMP
Keith FLOYD	BP	)
Karl SANDVIK	IKU	)
Alister SKINNER	BGS	) Participants
Ulrich DEUTSCH	ITE	) on Leg 124 E
Dave STEERE	UDI	)
Mark WALTZ	UDI	
Michel TEXIER	ELF	
Jacques DELACOUR	IFP	
Jean-François LEVIER	IFP	

TAMU Staff

Glen FOSS
Steve HOWARD
Eugene POLLARD
Dan REUDELHUBER
Michael STORMS

Apologies

Claus MARX	ITE
Paul STANTON	EXXON

AGENDA

April 27 8.30 AM - 6.00 PM

1.	Introduction	C. SPARKS
2.	PCHM/PCOM meeting Dec. 88	"
3.	TEDCOM mandate	"
4.	New from NSF	A. SUTHERLAND
5.	ODP organisational changes	B. HARDING
6.	Leg 124 E - Trial of DCS	S. HOWARD
7.	Leg 124 E - Navidrill Test	M. STORMS
8.	ODP Long Range Plan/TEDCOM Response	C. SPARKS

April 28 8.30 AM - 3 PM

9.	Leg 124 E - Other tests	M. STORMS
10.	Update on tools development	M. STORMS
11.	Coring of Chert/Chalk	Discussion
12.	Slimhole logging	P. WORTHINGTON
13.	Wellbore Stability Research at U.T. Austin	M. CHENEVERT
14.	Legs 123-125. Operations reports	G. FOSS
15.	Engineering Legs 2 and 3	B. HARDING
16.	Physical Properties Measurements for improved Drilling/Coring	K. MORAN
17.	Next meeting	C. SPARKS

1. INTRODUCTION

Charles SPARKS welcomed members, liaisons and guests to the seventh TEDCOM meeting.

He presented the agenda and stressed that the TEDCOM had two very important tasks in front of it:

- to draw conclusions from the first engineering Leg (124 E) that took place in Jan/Fev. 1989 and in particular to assess the DCS, which had been built and tried as the result of a TEDCOM recommendation (of 4 Feb. 1988)

- to formulate the TEDCOM response to the ODP Long Range Plan (LRP).

2. PCHM/PCOM MEETING NOV./DEC. 1988

Charles SPARKS mentioned the principal points, of importance to the TEDCOM, that were brought up during the meetings.

The decision had been taken that, from now on, all future ODP Legs should be "science driven" instead of "regionally driven". Many panel chairmen regretted that communication was not better between TAMU and the various panels. They requested the presence of a TAMU engineer at their meetings, at least once a year. C. SPARKS had suggested the some panel chairmen attend TEDCOM meetings. Unfortunately neither of the two invited to the present meeting were able to attend.

Technical objectives brought up during the PCHM meeting were virtually unchanged from the previous year (see Appendix A).

3. TEDCOM MANDATE

C. SPARKS had noted that the TEDCOM terms of reference, in effect since the beginning of ODP, bore little relation to the way the TEDCOM operated, and indeed conflicted with TAMU's responsibilities. At the PCOM chairman's request, a revised wording was proposed by the TEDCOM (see Appendix B).

4. NEWS FROM NSF

Al SUTHERLAND presented histograms (see Appendix C) giving revised figures for the Eng. & Ops. budget for 1990, when compared with those presented at the sixth TEDCOM. He also presented the break down of the TAMU and total ODP budget over the past four years. Ship costs for 1990 are expected to be slightly less than for 1989.

A. SUTHERLAND outlined the program plan schedule (see Appendix C) and transmitted NSF's comments about engineering. NSF is particularly concerned to know:

- if ENG LEG 1 (124 E) results have been fully evaluated
- if engineering legs are considered to be of value and how they should be scheduled
- if we are ready for a 4 000 m DCS

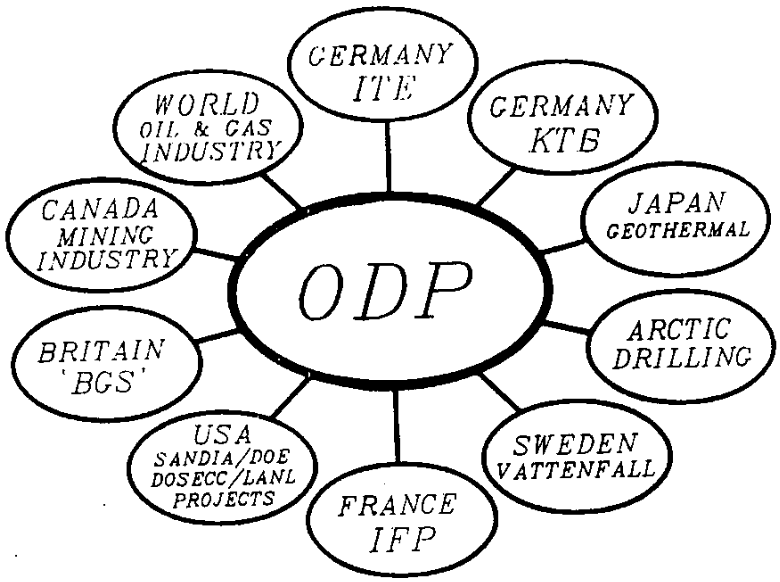
(see section 5 for TEDCOM comments on these points).

NSF also considered that JOIDES/PCOM should provide annual firm technical requirements, based on science.

When asked whether there was any chance of the USSR joining ODP, given their improved relationship with the US, A. SUTHERLAND replied that there were no developments in that direction at present.

5. ODP ORGANISATIONAL CHANGES

Barry HARDING presented the figure below, which summarizes the principal industries and organisations, throughout the world, on whose experience ODP is drawing.



6. LEG 124 E - TRIAL OF DCS

Steve HOWARD explained how the DCS test had been mounted following the TEDCOM recommentation of Feb. 1988. TAMU had first checked relevant experience in the US/Germany/Norway before defining details. It was thus decided to use a top driven system (instead of down hole turbine) with high speed narrow kerf diamond impregnated bits. A secondary heave compensator was incorporated in the design to limit weight on bit to 2500 +/-500 lbs.

The system had been designed, built, tested and shipped to Manila for Leg 124 E, in about eight months. This was a remarkable achievement by TAMU, as the chairman pointed out.

The test demonstrated the following:

- the system can be deployed in severe weather conditions
- the secondary compensator was effective in limiting W.O.B. as required. Furthermore, skilled operators could not control W.O.B. manually with the required accuracy, without the secondary compensator
- the mining system top drive could be used effectively in 1600 m of water, although it had not been used at high speed.

These results were very positive as Keith MILLHEIM stressed. They compensated for the disappointment of negligible core recovery (where 100-200 m had been hoped for). The discussion turned to ways of improving the DCS, which it was felt had not been given a fair trial on Leg 124 E, since basement was never found and terrible hole stability problems were encountered. (The performance of the DCS on Leg 124 E had been the object of several papers that TEDCOM members had already read, notably those by TAMU and leg participants Keith FLOYD, Karl SANDVIK and Alister SKINNER, Charles SPARKS.

Karl SANDVIK and Alister SKINNER mentioned that the key to the success of the DCS on the Bucentaur (used regularly for 200 m penetration in 500 m of water) was the stability of the API string. The API bit is deliberately locked into the formation, by drilling a short distance without circulation, just before deploying the DCS string. This provides an outside seal to the API bit, which ensures return circulation to the vessel via the annulus, when drilling with the DCS, and so avoids possible erosion of the API hole.

Keith FLOYD advocated retrying the DCS in 1500 m of water, in better conditions, before extrapolating towards 4000 m water depths where vibrational problems could be encountered.

Frank SCHUH mentioned that whirling vibrations can occur as a result of the two pipes sticking together and creating large centrifugal forces. This can be greatly reduced by increasing the lubricity of the annular fluid. Changing the rotational speed can be used to modify the string harmonics, as A. SKINNER pointed out.

Keith MILLHEIM mentioned that tool joints can cause damage to the well wall. He also suggested that a TEDCOM subcommittee be formed to cross check advice given to TAMU.

Frank SCHUH favoured suspending the API string from tensioners, so that the DCS could be operated from the rig floor (c.f. note on trial of DCS by C. SPARKS). Steve HOWARD mentioned that four tensioners would cost $600 000.

Mike STORMS mentioned that the great error of Leg 124 E, was to have agreed to hold the engineering leg in an area that had not been adequately surveyed and which turned out to be quite unsuitable.

Following the discussion, the TEDCOM adopted four recommendations:

- **the DCS should be retested as soon as possible in optimum conditions, with a cased hole, at a site already known to have basement at an acceptable level. Water depth should preferably be close to 1500 m. This should only be increased, if required by site considerations**

- **a TEDCOM subcommittee, composed of the following members, should be created to advise TAMU on mining drilling: W. SVENDSEN (coordinator), K. MILLHEIM, F. SCHUH, J. COOMBS, P. WICKLAND. Their associated travel expenses should be paid by J.O.I.**

- **A. SKINNER of B.G.S., a consultant with intimate knowledge of the DCS systems of the "Pholas" and the "Bucentaur", should be encouraged to participate in the above sub-committee. His travel expenses should be paid by J.O.I.**

- **TAMU should study ways of modifying the DCS, so as immobilize the lower end of the API string during all phases of DCS operation.**

7. LEG 124 E - NAVIDRILL TEST

Mike STORMS mentioned that the NCB had been deployed nine times during the leg. Mechanical failure had occurred five times, due to a defective motor (the new Mach IC failed to turn at all), mechanical separation of a core bit, and a broken thruster spring. On the four remaining runs some core was recovered, but bit plugging was a problem. Bit weight (W.O.B.) was between 4000-12000 lbs.

M. STORMS said the major problem of the NCB concept was that W.O.B. necessarily increased whenever the motor stalled. Some way should be found to vent the excess pressure in such a situation.

F. SCHUH suggested that a sand line be used to control W.O.B. M. STORMS added that it is theoretically possible to drill forward of the API bit by adding rod each time the NCB is pulled to recover core. This is quickly limited however by torque problems and weight on the sand line. He advocated more land testing, since penetration can be measured on land, but not at sea.

The normal procedure with the Navidrill is to ream down, after taking the core, rotating with circulation, to grind up the rubble and clean the hole.

Paul WORTHINGTON added that a gamma ray sensor could be used with the NCB to establish the position of partial cores. Prof. RISCHMULLER mentioned that such cores could be oriented using a micro-scanner. P. WORTHINGTON was doubtful that a micro-scanner would fit in a 4" hole.

8. LONG RANGE PLAN

Charles SPARKS introduced the plan and stressed that it was the result of four years discussion within the various panels and took into account the recommendations of COSOD 2. The plan was highly political with tough technical objectives. The TEDCOM was responsible for assessing as accurately as possible the ability to attain these objectives. If the TEDCOM were too cautious, it could spell the end of ODP in 1992. Likewise if the TEDCOM underestimated the difficulties, the consequences would be extremely serious for ODP.

After a very lengthy discussion, during which it was regretted that the technical objectives were not more precise, the enclosed carefully worded response of the TEDCOM was prepared and despatched to the PCOM meeting in Oslo by hand carrier (see Appendix D).

It was noted that the engineering of the 6 km DCS, shown in the budget table to begin in 1993, should be undertaken in 1989-92.

9. LEG 124 E - OTHER TESTS

Pressure Core Barrel (PCS)

Mike STORMS mentioned that the PCS had been deployed three times, of which two had been in the formation. Core samples had been recovered on both attempts. Full hydrostatic pressure had been recovered twice and the reason for the loss, on one attempt, had been identified (accumulator redressing problem). The tool was being improved, but the next required development was a pressure/temperature controlled lab chamber to which the core could be transfered.

Extended Core Barrel (XCB)

The new thread design had been effective in preventing over torque failures leading to a more reliable deep penetration (1000 m) coring system. The tool had been deployed in rugged environments without mechanical failure. The new cutting shoes had performed well except in Chert horizons.

The development of cutting shoes suitable for Chert formations would now be desirable, but may not be possible because of the inevitable high W.O.B. and low speed imposed by the system. Better circulation control to cutting shoes is also required. More experience with the XCB in different lithologies are required before a definite assessment can be made.

10. UPDATE ON TOOLS DEVELOPMENT

Core Orientation

Mike STORMS pointed out that there was no system commercially available today that could be used on Leg 130, as R. LARSON wished. He distributed a note (see Appendix E) giving the detailed response made by TAMU to PCOM on the subject.

Frank SCHUH mentioned that ARCO used a system some years ago that allowed cores to be orientated, but in the process it destroyed their natural magnetism. This would probably not be acceptable. He would nevertheless provide TAMU with the name of a contact person.

Sonic Core Monitor (SCM)

Mike STORMS mentioned that the SCM was under development with Diamont Boart. It was a downhole, self contained, core entry monitoring system using a sonic transducer. It was mated with the XCB.

The SCM will be under evaluation on Leg 126 but funding for continued development in 1990 has been cancelled.

Hydrolex Drilling Jars

A jar was deployed on Leg 124 but on retrieval was found to be impossible to rotate or stroke. This was probably the result of bending imposed during spudding and/on lack of lubrication. The design will be further evaluated on Leg 126. A modified and improved model of the jar will be deployed on Legs 127 and 128.

Barry HARDING asked Keith MILLHEIM if he would obtain permission to try jars with AMOCO.

High Temperature Drilling

Mike STORMS mentioned that TAMU's temperature objectives are progressive. TAMU is at present looking at ways of dealing with temperatures upto 400°C. They intended to use circulation for cooling purposes, although large flow rates would be required. TAMU is at present liaising with SANDIA and LANL.

Keith MILLHEIM concurred that it would make no sense for TAMU to work on these problems independently, given the great number of other subjects they have to treat. TAMU would do well to use a consultant.

Vibracoring

Mike STORMS explained that ODP was extremely interested in the application of vibracoring to ODP coring systems. They were particularly interested in applying it to:

- APC in loose flowing sands
- XCB in turbidities and chert/chalk
- DCS for enhanced life and improved penetration in crystalline rock.

Walter SVENDSEN pointed out that diamonds are fragile and do not like impacts. In mixed rock, diamonds could be sheared off.

M. STORMS added that TAMU is trying to keep up with research in this field. Jack PHEASANT of B.G.S. will be detached to TAMU shortly to work on vibracoring. He mentioned that the APC cannot at present be used in sand since it bounces back. As for the XCB, the sand gets washed out.

Atoll Drilling

TAMU have reviewed drilling records from the Enewetak coring and discussed them with Alister SKINNER who was the coring engineer concerned.

The DCS is being developed as a potential coring system for shallow water carbonate/reefal limestone lithologies.

11. CORING CHERT/CHALK - DISCUSSION

Mike STORMS mentioned that the only tool at present available to TAMU for coring chert/chalk was the NCB. The XCB had given poor results.

Keith MILLHEIM mentioned that AMOCO had got 100 % recovery in chert/shale, but emphasised that this cannot be done by drilling with water and impregnated bits. The latter ball up in soft interbedded layers. Surface set diamonds and oil based mud are essential. Alas TAMU cannot use oil based muds since they contaminate the cores.

Keith MILLHEIM said low bit weights were essential. It was important not to break off the chert below the bit. He recommended that the smallest possible cores be taken when drilling chert. The matrix must not be destroyed. Fluids are the key to success. AMOCO has drilled chert/limestone with compressive strengths upto 60 000 psi.

12. SLIMHOLE LOGGING

Paul WORTHINGTON reviewed the logging tools that are available as a function of hole diameter (see Appendix F). He pointed out that more than 75% of the information was lost when hole diameter was reduced from 6 1/4" to 4". The cost of developing new 4" versions of the tools would be quite horrendous, he added. He stressed that continuous cores do not mean that logging can be dispensed with. Measurements made insitu are complementary to and more precise than those made on cores, since the scale of material being measured is so much greater (about 100 times).

He pointed out that a workshop on "high temperature slimhole logging" had been proposed to JOI to be held towards the end of 1989 in conjunction with ODP, DOSECC, Continental Drilling and KTB.

About the Nankai leg (planned for late 1989), he added that the "geoprops probe" was indispensible for it. Furthermore the "geoprops probe" could not be used without the "NCB" and the "Wireline Packer". All three key tools for the Nankai Leg were experiencing problems at the moment, he noted.

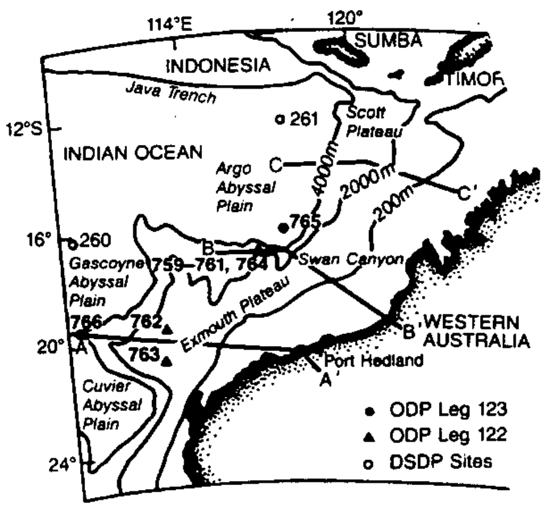
13. WELLBORE STABILITY RESEARCH AT U.T. AUSTIN

Martin CHENEVERT presented the research that he is involved in, related to wellbore stability. He explained that he was particularly concerned with the modelling of the state of stress in the immediate vicinity of the well wall. Some of the factors of concern are local swelling of shales pore pressures and resistivity. A plot of normal stress against octahedral shear stress can be separated into distinct "safe" and "failure" zones.

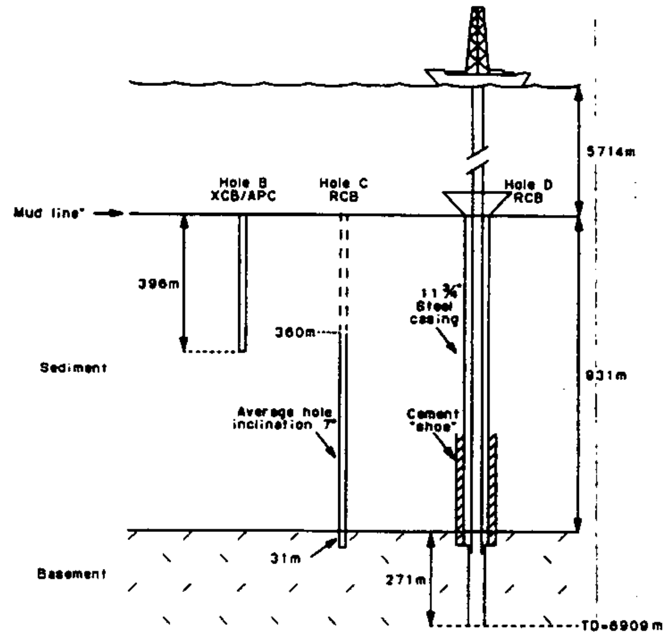
M. CHENEVERT quoted the operations report of Leg 124 and mentioned that some of the swelling observed was of mechanical origin and some of chemical origin. The first signs of swelling are stuck pipe. If clays are present, swelling is a potential problem. If there is no clay, inhibitive muds should not be used.

14. LEGS 123-125. OPERATIONS REPORTS

Glen FOSS explained that Leg 123 was spent investigating two sites on the Exmonth plateau (see sketch below), from 28 Aug. - 1 Nov. 1988, where a permant hole was hopefully established at site 765 D. A rentry core was set in 5714 m of water (deepest ever) and 930 m of 11 3/4" casing (longest ever in DSDP/ODP operations) was set to basement (see sketch below).



Leg 122-123 sites



Site 765

During this operation the derrick load reached a record 906 000 lbs.

Hole 765D was extensively logged. At one point a 20 m 3" diameter logging tool stuck inside the 11" casing and was only retrieved after working the line for more than four hours. No explanation was ever found for the sticking.

At the second site (766), in 4000 m of water, the RCB was used to continuously core through 440 m of sediment and 80 m of basalt. Cores in the upper sediment were highly disturbed and recovery was average. This improved below a chert layer at 200 mbsf. A 30 m section of coarse sand caused alarm but was drilled successfully without fill or torque.

During Leg 124 (Nov.-Dec. 88) two sites were investigated in the Celebes Sea and three sites in the Sulu Sea. Site 767, in 4916 m of water, was drilled to basement. Hole problems began at 714 mbsf and were explained by mechanical clay swelling in the lower hole section, induced by underbalanced drilling conditions. At 794 mbsf the pipe became irrevocably stuck and the BHA had to be shot off.

At site 768, in 4 395 m of water, three holes were drilled. Hole 768 B was abandoned at 364 mbsf when shows of hydrocarbon gas were detected. Hole 768 C was significant in being the deepest penetration hole yet drilled by ODP - to 1271 mbsf.

Leg 125 (Feb.-April 1989), following the engineering leg was devoted to drilling sites on the Mariana Arc and the Bonin Arc, just South of Japan. Very poor soil conditions had been encountered but at the final site 829 m of hole had been made in 3000 m of water. Problems had been encountered with gravels and fine volcanic sands.

When asked about the frequency at which BHAs had to be shot off as a result of stuck pipe problems, Barry HARDING replied that about five had been shot off in the first three years of ODP. More recently about ten had been shot off in the last eighteen months. The TEDCOM was alarmed by this increase.

15. ENGINEERING LEGS 2 AND 3

Barry HARDING mentioned that the second engineering leg had been postponed and was now scheduled to take place in May 1990. The top priority was to retry the DCS and some other tools such as the Navidrill and Jars. The tools would not be ready until late February after completion of land testing. A complete site survey prior to ENG. LEG 2 was essential, as had already been stressed during the discussion of Leg 124 E.

As for the third engineering leg, it was too early to discuss details. TAMU was not in favour of combining that Leg with the cleaning up of hole 504 B. The TEDCOM shared his point of view.

16. PHYSICAL PROPERTIES MEASUREMENTS FOR IMPROVED DRILLING/CORING

This point was included on the agenda following the TEDCOM recommendation of Feb. 1988, which said that physical properties measurements should be made on deck in order better to adapt drilling practices to the terrain encountered.

Kate MORAN (chairman of SMP) explained the present measurements made on board the JOIDES RESOLUTION. Glen FOSS explained the present drilling/coring procedures which consisted of using the APC followed by the XCB until refusal in both cases. After that a cone is normally dropped and the hole reentered with the RCB. Alternatively the latter is used to drill a new hole close by. He mentioned that cores could not be touched for two hours after retrieval until they had come into equilibrium with their surroundings.

K. MORAN suggested that further measurements could be made on cores not only to improve immediate drilling, but also to establish a data bank that could be useful for orientating future design and development of drilling/coring equipment.

The TEDCOM thought that what was most urgently required was information on drillability and on hole stability.

Following the discussion the TEDCOM adopted the following recommendation:

> **ODP should acquire an unconfined compression tester for hard rock to give immediate knowledge of compressive strengths to allow improved drilling and coring.**

K. MORAN said that SMP would look at the possibility of using XRD data to give indications on swelling that could lead to stuck pipe.

17. NEXT TEDCOM MEETING

It is tentatively suggested that the next meeting should take place in England to coincide with land testing of the DCS in Kent (probably January 1990).

ENGINEERING DEVELOPMENT
NEEDS & PRIORITIES IDENTIFIED BY PCHM

- Improved core recovery

- Drilling of:

    chalk-chert sequences

    unconsolidated sediments

    fractured rocks

    deep holes

    at high temperatures

APPENDIX A

TEDCOM MANDATE (April 27, 1989)

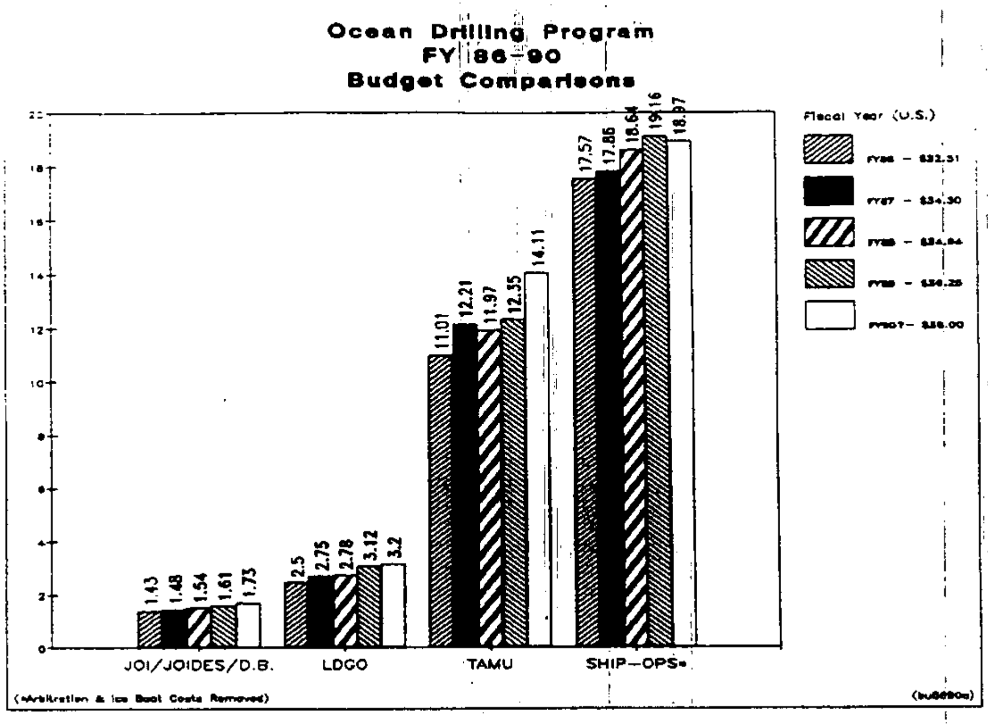
The TEDCOM is a consultative committee that is responsible for providing information and advice to the science operator (TAMU) on the technical developments necessary to meet the scientific objectives, defined by PCOM. It reports to PCOM on the required developments and necessary budgetary levels to meet them.

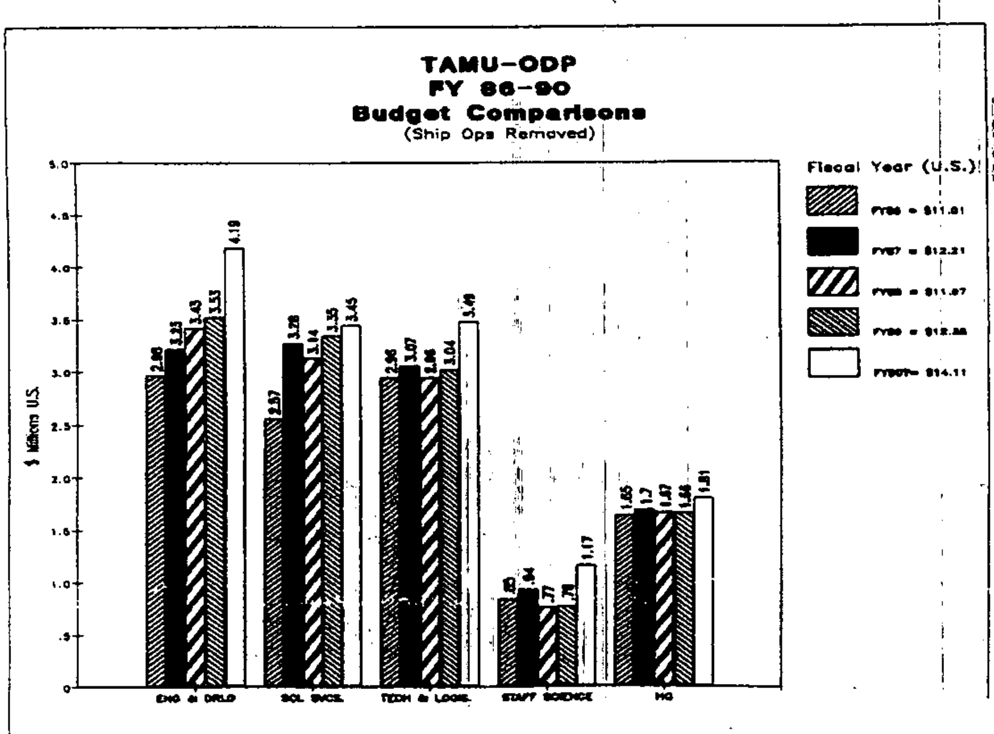
The TEDCOM assists the "Development Engineering & Drilling Operations" Group at TAMU with the conception of new tools and with the improvement of existing ones. It monitors the progress of their development. It occasionally assists TAMU/EDO with specific studies.

It organizes workshops and seminars on subjects relevant to the development program and arranges contacts between TAMU/EDO and companies or organizations, exterior to ODP, with pertinent experience.

TEDCOM members are generally engineers, nominated by PCOM. One of the tasks of the TEDCOM is to collaborate with the Downhole Measurements Panel.

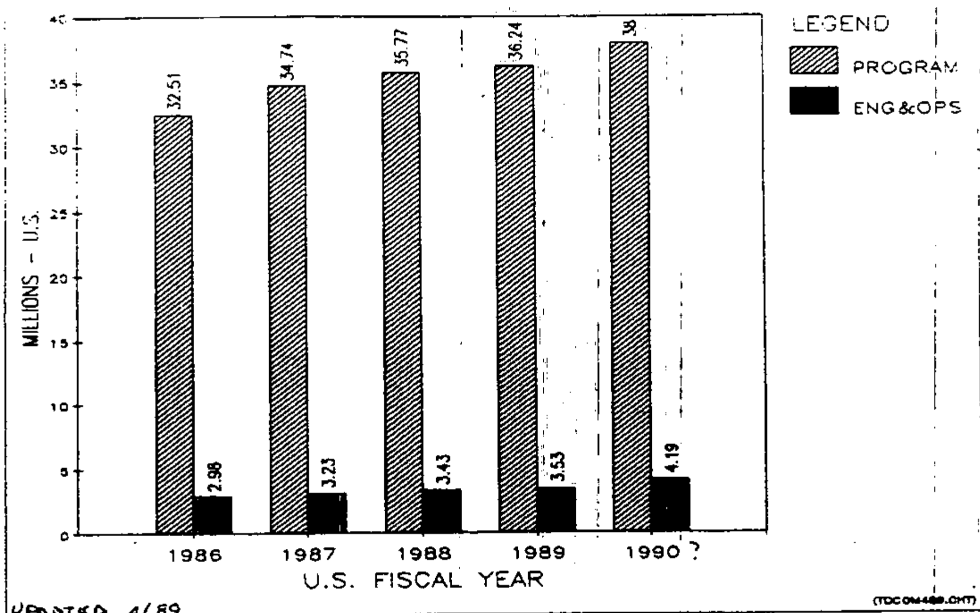
APPENDIX B


Ocean Drilling Program
FY 86-90
Budget Comparisons
Fiscal Year (U.S.)
1.43
1.48
1.54
1.61
1.73
2.5
2.75
2.78
3.12
3.2
11.01
12.21
11.97
12.35
14.11
17.57
17.86
18.64
19.16
18.97
JOI/JOIDES/D.B.
LDGO
TAMU
SHIP-OPS*

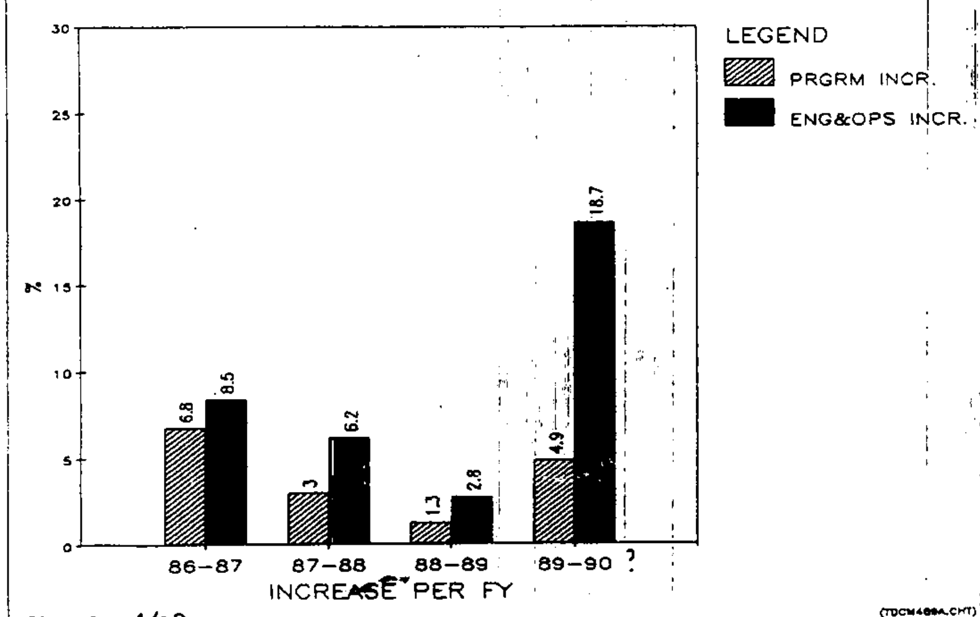

TAMU-ODP
FY 86-90
Budget Comparisons
(Ship Ops Removed)
Fiscal Year (U.S.)
$ Millions U.S.
4.19
1.17
ENG & DRLG
SCI. SVCS.
TECH & LOGIS.
STAFF SCIENCE
HQ

APPENDIX C

GROWTH OF ENG. & OPS IN ODP



GROWTH IN ENG & OPS IN THE ODP



PROGRAM PLAN SCHEDULE

DECEMBER	JOIDES SCIENCE PLAN
JANUARY	NSF BUDGET GUIDANCE TO JOI ⟶ TARGETS TO CONTRACTORS
FEBRUARY	BUDGET OUTLINE BCOM REVIEW
1 APRIL	DRAFT PLAN TO NSF FOR ADMINISTRATIVE REVIEW
1 JUNE	REVISED PLAN TO JOIDES EXCOM FOR REVIEW
AUGUST	FINAL PLAN TO NSF
SEPTEMBER	APPROVAL

April 27, 1989

TEDCOM RESPONSE TO ODP LONG RANGE PLAN
(Version 23 Nov. 88 - N. Pisias)

1) **TECHNICAL REQUIREMENTS/PROBLEMS LISTED**

The technical requirements are clearly defined in the LRP (see attached list) and appear to be correctly defined, given the scientific objectives. On the other hand, the list of problems related to drilling systems (see attached list from page 44) is incomplete and misleading.

The TEDCOM particularly endorses the remark that "we cannot predict the pace at which technological developments can be made, but it is essential that we commit enough resources, both in terms of engineering and operations, to a specific requirement to assume its proper completion". (LRP p. 54)

2) **PROBLEMS ALREADY UNDER STUDY**

Many of the requirements, that PCOM have drawn attention to, relate to problems that are already being addressed and will continue to be worked on as part of an on going, evolutionary process. These include drilling in chert/chalk sequences, improved core recovery, increased bit life, development of a pore water sampler and pressure core sampler.

3) **DRILLING/CORING CHERT/CHALK SEQUENCES**

It is not possible to be certain today that it will ever be possible to core all chert/chalk sequences. Success depends on firmness of the chalk matrix. The approach used at present is to develop methods that allow the position of the chert layers to be known as closely as possible; to control WOB and flow rates precisely; to drill with diamond bits. Land testing is essential to the success of this program.

4) **CORE RECOVERY**

In the case of core recovery, good progress is being made. ODP overall mean recovery rate today, in sedimentary formations and hard rock, is 67%. TAMU is continually working to improve this and has already set itself a target of 80%.

The LRP mentions a target of 75% in basement. ODP mean recovery rate to date in basement, mainly using the RCB, achieved on Legs 103 through 123 is 42 percent. The DCS promises greatly increased recovery, since, on land, rates of nearly 100% are achieved with such systems.

APPENDIX D

5) FIRST PHASE REQUIREMENTS NOT BEING ADDRESSED

Development work is not at present being done on the `absolute orientation of ALL core samples', because of budgetary and manpower insufficiency. On the other hand, APC cores are already routinely orientated. Hard rock core orientation will be addressed once an acceptable hard rock coring system (DCS or equivalent) has been developed.

Also for budgetary and manpower reasons, research on vibrocore sampling in sandy sequences has had to be deferred, although ITE (FRG) developments in this area are being closely followed.

6) IMPROVED HOLE STABILITY

With an open circulation (riserless) system, the key to stability, in difficult terrain, lies in the use of mud and casing and in leaving holes open (uncased) for the minimum possible time. PCOM should not imagine that hole stability problems are likely to improve significantly. Some academic research on continuous hole linings is being pursued, particularly in Norway, but has not been applied in the field. It's practical application is probably five years away.

7) VERY DEEP DRILLING

The LRP very deep drilling goals in hard rock are very ambitious (in 1989) and may not be realistic, particularly as industry is not presently doing any relevant research that would help ODP to reach these objectives. Nevertheless, the phased approach adopted in the LRP gives the best hope.

If the MOHO (5Km penetration) is the main objective of the LRP, an international symposium devoted to all related problems should be organized in the near future so that necessary research can be logically planned and shared between interested organizations.

Phase I and II objectives appear achievable with the mining coring system providing the necessary manpower and budget are made available.

It is interesting to note how the limit of routine drilling in the oil industry has been extended over the ten year period (but note: drilling in sedimentary sequences, in shallow water, with virtually no coring). In 1979, 3000 m of hole was routine. In 1989 the industry is drilling regularly to 5 - 6 km. However this is the result of considerable research and development. But to anticipated this kind of continued development in the future is not realistic.

(Note: If similar evolution cannot be noted when comparing ODP achievements with those of DSDP, it is because increased depth has not been an ODP objective. However, ODP is far more effective than DSDP in core recovery and number of holes drilled, mainly due to increased engineering effort and budget.)

The required technology to reach the MOHO cannot be defined in detail today but could well be evolved and extrapolated today from the ODP diamond coring system (DCS), the KTB project and the Swedish Vattenfall project.

ODP should explore different scenarios and carryout feasibility studies with cost estimates NOW to see how such extrapolation could be logically planned and phased.

8) **DEEP DRILLING WITH CIRCULATION AND SAFETY CONTROL**

No water depth is given. Possible use of alternate platform is mentioned.

It is possible to consider transforming the DCS into a mini riser system with circulation back to the ship through the annulus between the API string and the DCS tubing. That would allow mud to be used to give improved hole stability. The TEDCOM recommends that such a study be undertaken immediately. A safety system, should be incorporated into the design.

The TEDCOM has already concluded that drilling from the JOIDES RESOLUTION with an oil industry type riser should not be considered. Even a 10" slimline riser would require excessive tension in 5 km of water. In great water depths the diameter and annular area must be kept as small as possible to limit top tension to an acceptable level.

The oil industry does not today have any proven solution for riser drilling in water depths in excess of 2.5 km. If the water depth is much less than this limit, ODP could use an alternate platform for riser drilling, or adapt the mini riser DCS system.

However, it should be noted that the oil industry might well be very interested by the development of a drilling system with mini riser and well control, for drilling in very deep water.

9) **LRP TEXT MODIFICATION**

LRP page 9 Line 32. The phrase "...have pushed riserless drilling to its limits" should be removed, since it is not necessarily true.

10) **SUPERLEGS**

LRP refers to several objectives requiring multiple legs or "superlegs". For such legs the standard ODP planning for 60 day legs should stop, since interruptions will be too disruptive. An independent vessel (wareship) should be considered for supplies and crew changes. It might even improve efficiency on present ODP operations. Cost of a wareship could be around $3M per year.

11) **ENGINEERING LEGS AND OTHER TESTING**

The TEDCOM:

- endorses JOIDES decision to hold `periodic' engineering legs. The length, frequency and location of these legs should be determined by the requirements of engineering development, rather than by the convenience of a calendar fixed well in advance. Site selection and survey are of the greatest importance for the success of an engineering leg.

- recommends that the engineering legs be supplemented by land tests in certain cases such as to drill chert/chalk sequences, with the DCS.

12) **DOWNHOLE MEASUREMENTS**

Many of the technical requirements relate to improvements in Downhole Measurements. In particular the TEDCOM recommends that a workshop on high temperature slimhole logging be convened in the near future. The TEDCOM encourages continued liaison with DMP to ensure that technical developments are correctly coordinated.

13) **BUDGET**

The TEDCOM wishes to reiterate firmly that engineering development cannot take place at the required rate if the corresponding budget is not made available. This point has been raised frequently by TEDCOM chairmen at meetings of the planning committee (PCOM). The budget of the Development Engineering Office is not being increased in proportion to the demands made by the program. In 1986, the TEDCOM recommended that their budget be increased to $5M by 1991.

The budget figures, for phases 2 and 3, presented in Table 3 must be very approximate, since the corresponding problems have not bee posed precisely and the technical solutions have not been developed. Nevertheless, the TEDCOM feels that the budgeted figures for these phases may be considerably underestimated.

In order to accomplish the significant developments contemplated by the LRP, the TEDCOM recommends the allocation of specific funds for the evaluation and more accurate estimation of the corresponding costs.

ODP LONG RANGE PLANNING DOCUMENT
(23 Nov. 1988 - N.Pisias)

TECHNICAL REQUIREMENTS LISTED (see pages 43,44 and 48-52)

1) **Drilling/sampling/logging**
in young brecciated, sometime hot (>400 C), igneous rocks;

2) **Drilling very deep sites**
in a) igneous rocks
b) unconsolidated, sometimes sandy, sedimentary sections
c) clastic sequences with complete circulation and safety control (possibly from alternate platform) (p.50)

Penetration targets:
. 1992 - 1 km of basement - 75% recovery
. 1996 - 2-3 km, well into Layer 3
. 2000 - entire crust to MOHO
(5 km hole - assumed to be in 5 km of water)

3) **Improvements in Downhole measurements**
especially in high temperature/corrosive environments
- downhole seismometers
- in-situ physical properties
- pore water sampling
- dissolved gas sampling

4) **Improved drilling and sample recovery**
- complete and undisturbed recovery in soft and semi-soft sedimentary sequences
- absolute orientation of all samples
- chert/chalk sequences (p.52)
- shallow water carbonates (p.52)

5) **Alternative drilling platforms**
- very shallow water drilling
- for areas with extensive sea ice

DRILLING SYSTEM - MAJOR PROBLEMS LISTED IN LRP (see page 44)

1) **Penetration and sampling**
   of young, highly fractured, extrusive basalts
   (upper part of Layer 2)

2) **Low penetration rates**
   - short bit life
   - hole instability
   - incomplete flushings of cuttings in deep crustal holes

3) **Low recovery rates**

Table 3. Cost Estimates for Additional Engineering and Operational Expenses

Engineering and Operational Requirements	Scientific Objective Addressed	Phase I 1989-1992 ($1000)	Phase II 1993-1996 ($1000)	Phase III 1997-2002 ($1000)
1. 4km Diamond Coring System.	1,2,3,4,7,8,9, 13	1390.	-----	-----
2. 6km DCS	1,2,3,4,7,8,9, 10,11,13	-----	1000.	200.
3. Slimline riser and blow out preventor	1,2,3,7,8,9,10, 11	300.	5000.	1500.
4. Improved sediment coring Systems	7,8,9,10,11,12, 13	250.	200.	150.
5. Borehole Seismometers and Operations of Seismic systems.	2,4,5	600.	600.	600.
6. High-temp systems.	3,4,11	1000.	1510.	750.
7. Improved Packer and fluid samplers.	4,5,8,11	800.	500.	300.
8. Oriented core samples.	1,2,5,6	250.	250.	-----
9. In-situ pressure sampler.	7,8	250.	250.	150.
10. Slimline logging and borehole exp.	1,2,3,4,7,8,9, 10,11,13	650.	2000.	-----
TOTAL	1,7,8,13,15	5490.	11310.	3650.

The University of Rhode Island Graduate School of Oceanography
Narragansett Bay Campus, Narragansett, RI 02882-1197

December 5, 1988

RECEIVED
DEC 13 1988
Hawaii Institute
University of Hawaii
88-425

Dr. Ralph Moberly, PCOM Chairman
Hawaii Institute of Geophysics
University of Hawaii
2525 Correa Road
Honolulu, Hawaii 96822

Dear Ralph:

I would like to request DMP, TEDCOM , and TAMU/ODP to investigate the possibility of developing or buying a system for hard rock core orientation to be operational for the geochemical reference hole drilling presently planned for ODP Leg 130, February-March 1990. I believe that the most immediate potential result from this leg has nothing to do with geochemistry but with the remanent paleomagnetic vector orientations of the basalt samples and their implications for the early tectonic history of the Pacific plate. You will recall that one of the results of Leg 32 was the suggestion that in the Late Jurassic/Early Cretaceous the Pacific plate of that time was moving south, and that sometime during the Cretaceous this motion switched to the northward motion that we have subsequently observed. Although this suggestion was based only on remanent inclination information from basalts of DSDP 303, 304, and 307, you will also recall that we had onboard a prototype hard rock orientation device. This device consisted of a non-magnetic (Monel) drill collar, a damped compass capable of being photographed or otherwise recorded, and a scribing or scratching device just above the throat of the bit. It didn't work very well on Leg 32. Potentially such a device could provide remanent declination information that, coupled with remanent inclination and the polarity of the sample, would yield a unique paleomagnetic pole location estimate for the Pacific plate at M16 time on BON-8 and M24 time on MAR-4 on ODP 130. These results could be compared to the inclination results of Leg 32, paleomagnetic seamount analyses (ranging back to ~100 m.y.), skewness analysis of M1-M10 (Larson and Chase, 1972), and skewness analysis of M10-M25 that I am now analyzing.

This device could also be available for subsequent legs in the western Pacific (Shatskey Rise, Old Pacific, and Atolls and Guyots) and for other areas. Such a device to solve this specific problem was also recommended and emphasized by the USSAC Workshop on Paleomagnetic Reference Frames held in College Station in May 1988. I imagine that this technology exists in the oil industry and would not be difficult or expensive to adapt to ODP drilling. The scientific return on such a device would be great, and as Jerry Winterer said at the workshop, "We've been asking for core orientation since 1967, why do we always have to go back to square one?" (add your own emphasis).

Sincerely yours,

Roger

Roger L. Larson
Professor of Marine Geophysics

RLL:cs

APPENDIX E

SUMMARY STATEMENT

ODP HARD ROCK ORIENTATION CAPABILITIES

Introduction

The purpose of this statement is to clarify the ongoing question of ODP's current ability and plans to provide magnetically oriented hard rock cores. It is unfortunate that this question has become a source of confusion and disgruntlement on the part of the science community (as is evidenced by Roger Larson's Dec. 5 letter to Ralph Moberly and Roger's quote from Jerry Winterer). It is certainly time to let the scientific community know that the problem has been a failure to properly communicate the accurate information and nature of the problems ODP *faces*, not a case of non-response on the part of ODP to a reasonable science request for a technological capability. Also included is an explanation and cost estimate for a short term alternative approach to hard rock orientation to be ready for presentation at the upcoming TEDCOM meeting in College Station (April 27-28) as specifically requested by Moberly. This approach is not recommended by ODP Operations/Engineering because it is considered not to be cost effective nor is it expected to offer a high probability of achieving worthwhile scientific results.

Past History & Current State of the Art

In his letter to Moberly, Roger Larson points out that DSDP tried out a hard rock orientation system in 1973, that such technology has existed in the oil industry for many years, and that it "would not be difficult or expensive to adapt to ODP drilling." In these statements he concisely summarizes what is probably the consensus opinion of the ODP science community. He is quite correct about the DSDP experiment and the oil industry capability. He is quite mistaken about the adaptability of the technology to ODP. It would not only be difficult to adapt to ODP, it would be, at this point, a fruitless exercise.

The industry standard technique for achieving oriented hard rock samples (mimicked in the DSDP experiments) relies on scribing axial marks on the core pieces as they enter the core barrel. Simultaneously, a multishot compass/camera (elsewhere in the core barrel) records the azimuth direction of the primary scriber every few seconds. Later correlation is made between the scribe marks, the compass images on the multishot film, the master clock for timing the operation, and the depth of penetration of the drillstring at incremental times during the coring interval. The mining industry achieves oriented hard rock cores using the scriber/multishot system mated to a wireline retrievable core barrel very similar to ODP technology. The oil industry equipment that is available off the shelf is "conventional", meaning that the core barrels are not wireline deployable and are retrieved by tripping the entire drillstring. It should be noted that hard rock orientation is not an "every day" procedure for the oil industry since oil and gas reserves are not normally associated with crystalline rock lithologies.

The primary difference between the industrial hard rock orientation capabilities and ODP's analogous situation is the ability to achieve virtually 100% core recovery in hard rock. Industry coring specialists are able to achieve 100% recovery often enough to net some meaningful results in their orientation attempts. DSDP and ODP have rarely achieved near-100% core recovery in hard rock except in unpredictable, exceptional cases (the bottom of the gabbro hole drilled on Leg 118, for example.)

The issue of 100% recovery is fundamental to the existing technology for hard rock orientation. No technology now exists (or to my knowledge, has ever been developed) to orient rock cores without this prerequisite. The oil industry is very well aware of this; witness the following quote:

> "Accurate depth correlations can be very difficult to achieve in cases where core recovery is 90% or less. .... As core loss increases, orientation data eventually becomes meaningless since no reasonable correlation is possible between core depths and surface-recorded depth." [1]

The situation is actually worse than that. Not only can there be no reasonable depth correlation as recovery drops below 90%, there is also no reasonable correlation between scribed pieces of rock core and the Multishot pictures which provide the actual azimuth data, thus all of the orientation data derived becomes meaningless.

DSDP attempted hard rock orientation on Legs 32 and 34. The pertinent excepts from the operations reports for those legs are attached. The experiments were ambitious but a little naive since even if the hardware problems described had not occurred the results still would have been dependent on 100% recovery whenever the orientation system was used. This was an unrealistic expectation as the recovery statistics of the two cruises eventually proved.

The next obvious question is: why can industry achieve 100% recovery in hard rock (at least for a portion of the time) while ODP essentially cannot? There are many reasons for this difference but the two most significant are the types of bits used and the stability of the bit and bottomhole assembly while the coring process takes place. Both the oil and mining industries do their coring using diamond core bits working from either stable rigs (land or fixed offshore platforms) or from floating platforms in shallow water (relative to ODP typical depths) where the heave

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[1] Bleakly, D.C., et al, "Controlling Errors Minimizes Risk and Cost in Core Orientation," Oil & Gas Journal, Dec. 2, 1985.

compensation problem is greatly minimized. The number of organizations, worldwide, that attempt to routinely core hard rock from a floating platform using roller cone bits can literally be counted on one hand. None of these organizations has the ability to orient hard rock cores, either. A roller cone bit, under even ideal conditions, produces an irregularly cut, roughly cylindrical core which is poorly suited to scribing for orientation reference. Worse still, the core recovery percentage problem is directly a result of using roller cone core bits.

So why not use diamond core bits for achieving ODP oriented hard rock cores? Because repeated experiments have failed to demonstrate that they can be made to work at ODP operating depths, with ODP drillstring technology and ODP heave compensation capabilities. The same was true during DSDP. Diamond core bits have been attempted as early as DSDP Leg 1 and as recently as ODP Leg 111. The reason they are not used by ODP, despite continued advances by the diamond bit manufacturers, is that the success rate in terms of core recovery and bit life has never come close to justifying their expense, which is from three to ten times the cost of a comparable, more durable and reliable roller cone bits. In fact if both were available at the same price the roller cone bits would be considered significantly more desireable. Most of the DSDP/ODP experiments with large diamond bits have resulted in performance far below expectations and premature pipe round trips for replacement of dull bits.

ODP Plans and Alternatives

There are three approaches to the problem of achieving a viable hard rock orientation capability available to ODP, the last two of which are currently under development.

1. A near-term solution using a modification of oilfield technology could be adopted specifically to satisfy a request for providing the capability on the Geochemical Reference Leg. This approach would be expected to have a very low probability of success (less than 20%) and is not recommended by ODP Development Engineering department although it is feasible. The cost would be about $120K. (See details below).

2. The most appropriate solution is to wait until the Diamond Coring System is developed to the point of common usage. Near 100% recovery in hard rock is a reasonable expectation of the DCS under good circumstances, particularly if the formation is not highly fractured. The off-the-shelf orientation technology available from the mining industry could then be readily adapted to ODP operations. This would, of course, entail some additional expense since all hardware in the vicinity of the Multishot compass would be have to be non-magnetic materials in place of the steel parts normally used.

3. An development project being pursued presently by ODP may ultimately solve the hard rock orientation puzzle. The system is known as the Sonic Core Monitor (SCM). It uses a small sonic transducer mounted inside the core barrel to continuously monitor the ingress of core as the coring process proceeds. This device will record the core entry over time and provide the data required to identify the exact locations of any lost core, thus filling in the gaps in the information chain caused by less-than-100% recovery and making a "conventional" hard rock coring system viable for ODP operations. The SCM system was on board for Leg 124E but was not tested downhole. It is currently configured to mate with the XCB coring system, but, if proven effective on Leg 126, could be adapted to the Rotary Coring (RCB) system in order to mate with an orientation system for hard rock.

Note: Prior to the writing of this statement the funds for the Sonic Core Monitor development work were deleted from the ODP FY'90 budget on the basis of identified scientific priorities. This will certainly delay development of this technology as a means to help achieve hard rock core orientation.

<u>What Can be Provided in Time for the Geochemical Reference Leg?</u>

Assuming that the Geochemical Reference Leg is scheduled as Leg 129 (starting in October 1989) the time between a go-ahead decision and shipping deadlines for the Leg would limit the choice of hard rock orientation systems to two possibilities.

One would be adaptation of the Sonic Core monitor system to an RCB system set up for hard rock orientation. This would require an expenditure of about $75K plus significant realignment of ODP technical priorities (it is not currently planned to adapt the SCM to the RCB system until it shows significant merit using the XCB as the test bed.) This approach for the Geochemical Reference Leg would rely on complete prototype success in testing the SCM on Leg 126. It also assumes that a non-magnetic RCB system can be produced (using some parts retained from DSDP) including all new, non-magnetic components for the SCM system. It also assumes that the Multishot pressure case and SCM system can all coexist inside the special RCB core barrel and still leave enough space for a meaningful length of core. A reasonable guess would be that space for the core itself would be limited to 3-5m, compared to a normal 9.5m. All of the above is feasible but requires a number of separate events to "go just right" for the final package to be ready and operational for Leg 129.

The second possibility for near-term provision of oriented hard rock core is the hybrid approach mentioned above. This would consist of the following:

- Buy several large diameter diamond core bits (9-7/8" x 2-3-8").
- Produce the non-magnetic RBC system (described above in conjunction with the SCM adaptation.)
- Plan on selected reentries with the required special bottomhole assembly into a reentry hole previously drilled to hard rock with roller cone bits (individual diamond bits will not cope with sediments, possible chert, AND hard rock)
- Expect to take very short cores (1 - 2 meters long) in order to stand any chance of achieving near-100% recovery.

The anticipated cost for this option is about $120K. It could be ready for Leg 129 (assuming a May 1st go-ahead) but would not likely leave time in the development and procurement cycle for land testing. Extra rig time on the cruise, above and beyond normal coring requirements, would include the time required to do a reentry cone/casing emplacement, more-frequent-than-normal reentries, extra BHA make-ups, and extra wireline trips required by abnormally short core advances. This approach is not recommended and is provided to outline the magnitude of the problem so that a proper value judgement can be made in the tradeoff between time, money and potential scientific results.

LOGGING CAPABILITY IN BOREHOLES

OF DIFFERENT DIAMETERS

Tool	Tool Diameter (inches)	Slimhole Capability	Loggable Hole Diameter			
			6½"	5½"	4½"	4"
Phasor Induction	3 5/8	No	X	X		
Dual Induction	3 5/8	Yes	X	X	X	
Dual Laterolog	3 5/8	Yes	X	X		
HEL Dual Laterolog	2 3/4	Yes	X	X	X	X
Microlog	4 1/2	No	X	X		
Dipmeter	3 5/8	No	X	X		
FMS	3 5/8	No	X	X		
Induced Polarization	2 3/4	?	X	X	X	X
Full Waveform Sonic	3 5/8	No	X	X		
HEL Velocity	2 3/4	Yes	X	X	X	
Slimhole Velocity	1 11/16	Yes	X	X	X	X
Thermal/Epithermal Neutron Porosity	3 5/8	No	X	X		
HEL Porosity	2 3/4	Yes	X	X	X	
Slimhole Porosity	1 11/16	Yes	X	X	X	X

APPENDIX F

Lithodensity	$3\frac{5}{8}$	No	X	X		
HEL Lithodensity	$2\frac{3}{4}$	Yes	X	X	X	
Slimhole Density	$1\frac{11}{16}$	Yes	X	X	X	X
Induced Gamma Spectral (GST)	$3\frac{5}{8}$	No	X	X		
Aluminium Activation	$3\frac{5}{8}$	No	X	X		
Natural Gamma Spectral (NGT)	$3\frac{5}{8}$	No	X	X		
Natural Gamma	$3\frac{5}{8}$	Yes	X	X		
Borehole Televiewer	$3\frac{5}{8}$	Yes	X	X		
Slimhole BHTV	$1\frac{11}{16}$	Yes	X	X	X	X
Borehole Gravimeter	$3\frac{5}{8}$	No	X	X		
Magnetometer	$3\frac{5}{8}$	?	X	X		
Drill-string Packer	$3\frac{5}{8}$	Yes	X	X	X	X
Wireline Packer	$3\frac{5}{8}$	No	X	X		
Borehole Fluid Sampler	$1\frac{11}{16}$	Yes	X	X	X	X
Packed-off Fluid Sampler	$3\frac{5}{8}$	No	X	X		
VSP Multi-shuttle 3-component	$3\frac{5}{8}$	No	X	X		
VSP Single 3-component	$3\frac{5}{8}$	No	X	X		
VSP Single vertical component	$3\frac{5}{8}$	No	X	X		