REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*: 7/19/2000

2. REPORT ~~DATE~~ TYPE: FINAL

3. DATES COVERED *(From - To)*: 5/99 - 9/99

4. TITLE AND SUBTITLE: "Geologic Clutter Reduction in Shallow Water" workshop

5a. CONTRACT NUMBER:

5b. GRANT NUMBER: N00014-99-1-0807

5c. PROGRAM ELEMENT NUMBER:

5d. PROJECT NUMBER: 99PR06658-00

5e. TASK NUMBER:

5f. WORK UNIT NUMBER:

6. AUTHOR(S): James A. Austin, JR
Symposium Manager

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES):
The University of Texas at Austin
Office of Sponsored Projects
PO Box 7726
Austin, TX 78713-7726

8. PERFORMING ORGANIZATION REPORT NUMBER:

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES):
Office of Naval Research
ONR 252: Julia M. Gallmon
Ballston Centre Tower One
800 North Quincy Street
Arlington, VA 22217-5660

10. SPONSOR/MONITOR'S ACRONYM(S): ONR

11. SPONSORING/MONITORING AGENCY REPORT NUMBER:

12. DISTRIBUTION AVAILABILITY STATEMENT: APPROVED FOR PUBLIC RELEASE

13. SUPPLEMENTARY NOTES:

14. ABSTRACT:

15. SUBJECT TERMS:

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
					James A. Austin Jr.
					19b. TELEPONE NUMBER *(Include area code)*: (512) 471-0450

"An Analysis of Geologic Clutter in Shallow Water"
A Workshop
June 29-30, 1999
Arlington, VA

Purpose: A ~5-year field and analysis effort to understand, measure, and predict lateral and vertical, naturally-occurring heterogeneities that may produce discrete acoustic returns at low grazing angles, "geologic clutter", in a mid-outer shelf test site was discussed and developed at a 29-30 June, 1999, workshop. The workshop included both geologists/geophysicists and acousticians, and the planned initiative involves both geologic/geophysical and ocean acoustics/signal processing components.

Premise: In any littoral area, buried geologic features can contribute significantly to acoustic reverberation and clutter, which affect tactical ASW sonar systems. Proper acoustic processing, coupled with quantitative geologic models, can be used to distinguish these buried features from man-made targets. STRATAFORM studies on the continental shelf off New Jersey have shown a general lack of predictability of the shallow subsurface based simply on seafloor imagery, even given 100% coverage (Figure 1).

Goals and Objectives: A good candidate site was identified off the U.S. east coast, the ONR/STRATAFORM New Jersey shelf "natural laboratory". The participants developed a precise acoustic reverberation experiment at this site to understand, characterize, and potentially mitigate geologic clutter, so that the false detections likely to occur on tactical sonar systems in this type of marine geologic environment around the world can be characterized properly (Figure 2). The goal of the U.S. east coast field experiments in 2000 and 2001 is to understand the process of acoustic reverberation from the seabed in shallow water, with the objectives of:
- Designing physics-based signal processing algorithms to distinguish the echoes from naturally-occurring features on the world's continental shelves (e.g., iceberg scours, shallow gas accumulations, outcrops of high-amplitude shallow subsurface reflectors, shallowly-buried meandering channels) from man-made targets of similar dimensions (e.g., submarines).
- Predicting the distribution and properties of "geo-clutter" at continental margin sites of interest around the world.

A. FIELD EXPERIMENTS

Overriding Goals - 1) to assess geologic clutter (defined as scatter from acoustically target-like features of geological origin) and reverberation (defined as diffuse, random scattering from normally occurring roughness and heterogeneity) issues in a well-characterized shallow-water (~50-250 m) environment.
- For example, how does clutter relate to the ever-present diffuse component of reverberation, with increasing range and changes in source frequency?
- The mid-outer continental shelf off New Jersey provides an opportunity, because both bathymetry (a known cause of prominent echo returns) and the shallow subsurface have been mapped in detail as a result of STRATAFORM. Furthermore, this STRATAFORM area is believed to be typical of many of the world's continental shelf geologic environments.
2) to predict the distribution and properties of "geo-clutter" at continental margin sites of interest around the world. Given relatively low grazing angles and lower frequencies of new sonar systems, there are situations and locations where the sonar signal will penetrate the seafloor. Subsurface geological structures that have high-angle reflecting surfaces

can return false alarms. Examples include steep-walled channels from shallowly buried paleo-river valleys (Figure 1) and iceberg furrows or scours.

Needs - a controlled experiment, in two phases (see below), where the mapped geomorphology of the area is co-registered with the sonar systems' charted returns.

Length and Width Scales:
- Assumption: that the primary discrete scatterers are surface (e.g., outcrops of high-amplitude subsurface reflectors, iceberg scours) and shallow subbottom features (e.g., drainage channels, up to hundreds of meters across and 5-20 m deep, buried at variable depths up to 5 m).
- The following sonar parameters are appropriate:

Range	Frequency	Sonar Beamwidth	Footprint Area
1-30 km	100-3.5 kHz*	1-5°	variable**

*with emphasis on frequencies at the low-end, <1 kHz (~200 Hz ideal) to maximize acoustic penetration of the seafloor. Source level: >210 db (to get above the ambient noise environment, and to compensate for transmission loss at 5 km range).

**10^2 to 10^6 sq. m., but a function of range and pulse length and, for matched filters, signal-to-noise ratio.

Field Work: to be accomplished in two phases:

Phase I. A. Do a monostatic (single-ship) acoustics reconnaissance experiment, prefaced by some modeling (see below):
- Goal: To determine if seafloor and shallow sub-seafloor features already identified and precisely mapped on the middle-outer continental shelf off New Jersey produce "geo-clutter."
- Objectives:
  • What clutter can be attributed to surface- or subsurface-features?
  • Is observed high reverberation diffuse/smeared or discrete?
- In advance:
  • Draw tracks for the acoustics experiment, based upon preliminary modeling (ACTION: Makris, see below)
  • Prepare environmental assessment (ACTION: Austin, with Navy involvement regarding marine mammal issues).
  • The naturally occurring geomorphology will be exploited in the experiment design to mitigate the inherent left-right ambiguities of the receiving array system as much as possible.
- When: 2000
- Experiment strategy:
  • Assess the (range-dependent) resolution footprint of the sonars to be used, then compare them with the physical distribution and sizes of the geologic features that are the presumed sources of the scattering.
  • Targets: 1) Concentrate on candidate geo-clutter scatterers (so-called "hot spots"), from a list of surface and subsurface features for the middle-outer New Jersey shelf compiled by STRATAFORM investigators: iceberg scours, incised/buried river channels, point sources (e.g., gravel lags at the bases of or near channel incisions, boulders 0.5-3 m in diameter - ice-rafted debris, in the vicinity of iceberg scours), gas-enhanced reflectors, outcrops of high-amplitude subsurface reflectors (e.g., "R"). 2) Place some known scatterers in the imaging field for calibration, e.g., a hose hanging in the water column. 3) Also consider scattering from fish targets.

• Approach: survey multiple boxes of varying size around "hot spots" or candidate geo-clutter scatterers. Specifically, attempt to identify a regional set of scatterers (perhaps by surveying a 10 km x 10 km box), then target those for more intensive work (ref. ARSRP), perhaps multiple boxes of 2 km x 2 km. Consider azimuthal returns when preparing tracks.

- Propagation environment:
  - Determine times of optimal water column conditions to probe distant subbottom features, and at the same time avoid contamination from internal waves, surface gravity waves, and fish concentrations.
  - Avoid times of pronounced internal wave activity and peak hurricane season.
  - Seek advice from knowledgeable physical oceanographers (e.g., those at Woods Hole Oceanographic Institution).
  - Additional needs: CTD and thermistor data.
- Investigate civilian (UNOLS) platform options (e.g., the *Cape Henlopen*), depending upon the source(s) to be deployed.
- Investigate potential for acquisition and use of an autonomous source.

(- ALTERNATE PLAN: If discrete clutter targets cannot be isolated off New Jersey after the recon experiment, then consider coordinated acoustics/geophysical fieldwork in another east coast North America geographic area of known scattering/clutter, e.g., the 3D imaged site on the Scotian Shelf. ACTION: Gauss will make a start at compiling a list of areas that have adequate acoustic databases. Then, the geophysicists will attempt to overlay areas [e.g., the Scotian Shelf, Adriatic] where adequate geological/geophysical characterizaton also exists.)

Phase I. B. Provide additional geophysical characterization as appropriate, depending upon the results of the Phase I A. experiment:
- Goal: To provide precise 2D and 3D (as necessary) seismic image maps of both the seafloor and shallow sub-seafloor in the vicinity of candidate geo-clutter scatterers, as identified by the Phase I A. acoustics recon experiment.
- When: minimum of 3 months from Phase I A. Avoid conflict with, but possibly leverage, planned Japanese, low-frequency bottom-inversion experiment at the New Jersey STRATAFORM site in fall, 2000.
- Area: nested geophysical surveys, specifically 1) multibeam bathymetry/sidescan imagery at 100% coverage and 2) 2D and 3D (as necessary) chirp sonar surveys, dimensions of all survey coverage TBD by both preliminary modeling and Phase I A. results. Perhaps a 10 km x 10 km box for "coarse" sampling (e.g., 2D chirp sonar profiling), followed by one or more smaller boxes (perhaps 2 km x 2 km each) for potentially 3D high-resolution seismic (chirp sonar) imaging.
- Investigate civilian platform (UNOLS) options and survey systems (e.g., Florida Atlantic University chirp sonar).
- Additional swath mapping as needed to survey "hot spots" (see above) fully.

Phase II. Use the SACLANT vessel *Alliance*, or, if necessary, another capable vessel, for a comprehensive, bistatic experiment with a second civilian (UNOLS) platform:
- Goal: To assess geologic clutter and reverberation issues, with increasing range and changes in sonar source frequency, within a well-characterized shallow-water (~50-250 m) continental shelf environment that can be viewed as typical of such environments encountered by tactical Navy assets around the world.
- When: 2001. (Note: After Phase I A. but before this experiment, consider the possibility of some additional acoustics reconnaissance, perhaps using a "gray ship" with a 53C (3.5 kHz) sonar, or some other tactical system(s), TBD).

- SACLANT vessel advantages: calibrated instruments, including a 128-element receiving array, suitable sources (ref. ARSRP).
- Experiment strategy:
  - Conduct short- and long-range scatter experiments.
  - Do synthetic aperture work, using a towed array.
  - Deploy thermistor strings, to acquire knowledge of the water column (esp. the upper 30 m., but including sea-surface to the seafloor).
  - Additional needs: SIMRAD fish-finder, chirp sonar control, cores (PROD) and related measurements for determining the *in situ* velocity field of the seafloor and shallow subsurface, CTD, sea surface roughness (satellite data - SeaWifs and/or directional wave buoys), and other detailed measurements as necessary of the bottom, water column, and sea conditions.

B. MODELING: geological/acoustics/signal processing

I. FY 1999: Preliminary modeling (ACTION: Makris), using input bathymetry and other STRATAFORM data as necessary (ACTION: Goff et al.), to determine potential for reverberation from various types of seafloor/shallow sub-seafloor potential targets.
- Assume 2x background noise (in dB relative to 1 microPascal, per Hz, corrected to reflect omnidirectional reception), as a minimum criterion for a potential scatterer.
- Consider azimuthal dependance of returns (ref. ARSRP).
- Consider geological and geoacoustic parameters (bathymetry, trends of shallow-subsurface drainage patterns, impedance, etc.)

II. FY 2000 and beyond:
Goal: Analyze reverberation/scatter and clutter. Do the two track each other?
1.) NRL: both New Jersey-specific and (ongoing) general modeling -
  - Separate out different scattering/clutter mechanisms: broadband models, geoacoustic inversion techniques, clutter models (empirical and physics-based), reverberation and active system performance models.
  - Invert chirp sonar data (to be collected off New Jersey as part of Phase I. B.) and compare it to cored data (Figures 3 and 4).

2) FAU:
  - Conduct chirp sonar surveys over the band 1-40 kHz, with 10 cm subbottom resolution.
  - Invert the chirp sonar data to generate impedance and attenuation profiles of the top 10-20 m of sediment.
  - Compare these to core data, as input to models that predict acoustic propagation.

3.) SPAWAR:
  - Continue modeling on the subject of geologic clutter/false alarm frequency.
  - Continue broadband (source) Parabolic Equation (PE) calculations.
  - More false alarms seem to come in at mid-ranges than at long ranges. Why?

4.) NUWC:
  - Signatures of reverberation: scattering effects near the source, decaying with increasing range, and changing temporally.
  - Interface with planning for field experiments so that they are designed to minimize complicating effects of propagation changes.

5.) Signal processing (e.g., APL/University of Washington) - consider strategies for interfacing with signal processors, to ensure that acoustic measurements include attributes important to extended echo-ranging systems, such as clutter statistics and echo features employed in classification and tracking algorithms.

6.) Geoacoustics (e.g., University of Delaware/MIT):
  - Convert geology into the parameter suite appropriate to acoustics: compressional + shear wave suite, density, attenuation (Figures 3-5).

• What should be done with cores (to be collected in summer 2000 under STRATAFORM)? For example, relate shear wave suite to void ratio/porosity, for both sand- and clay-dominated sediments.

7.) NAVOCEANO:

• analyze data acquired in the Phase I. A. acoustics reconnaissance experiment (summer 2000) for geo-clutter and bottom loss estimates.

• continue databasing efforts and integration, to facilitate availability of results of 2000 and 2001 geo-clutter field operations, and related data processing and modeling, to tactical Navy assets around the world that can make use of them.

8.) INSTAAR: predict the distribution and properties of geologic features responsible for geo-clutter at continental margin sites of interest around the world.

• Define the character of different kinds of geological features believed to be responsible for geo-clutter (size, shape, depth, physical properties).

• Ascertain the spatial distribution of known features (buried bedforms; buried river channels flooded by rising sea level; buried subglacial channels, flutes, iceberg furrows; buried flood channels [i.e., hyperpycnal channels], buried tidal channels).

• Use these guidelines to identify what we know (literature survey, develop global atlas of features and characteristics).

• Merge global databases (bathymetry [Geosat, etc.]; river location; sediment load; discharge magnitude; tidal energy; ocean wave energy; paleoclimate; sea-level fluctuations last ~18 kyrs; ice sheet history; geological constraints [tectonics, subsidence]) in order to help predict most likely settings of particular features.

• Develop predictive models (statistical theory, probability, scaling) and apply to margins of interest.

• Verify predictive models in known geo-clutter - rich areas (i.e., blind test).

C. COSTS

<u>**Assumption:**</u> "Geo-Clutter" initiative will constitute a ~5-year program, FY1999-FY2004 (inclusive):

<u>FY1999</u>

- Tasks:
  - Preliminary "hot spot" target identification, STRATAFORM/New Jersey.
  - Design of the acoustics recon (Phase I A.) experiment; preliminary acoustical modeling.
- Target budget: <u>$200K</u>.

<u>FY2000</u>

- Tasks:
  - Phase I A. planning meeting - early calendar year, $30K.
  - Conduct Phase I A. experiment, early summer:
    - Shiptime (UNOLS?), 2 weeks @$15K/day, $210K.
    - Equipment (e.g., sound sources): $200K.
    - Personnel/data processing costs: $500K.
  - Conduct Phase I B. experiment(s), late summer - 1) Geophysical surveying, nested areas; 2) Swath mapping as necessary:
    - Shiptime (perhaps 2 ships, UNOLS), 4 weeks @ $15K/day, $420K.
    - Equipment (e.g., chirp sonar, swath mapping): $500K.
  - Personnel/data processing costs (including post-experiment analysis), $500K.
  - "Gray ship" surveying - time TBD.
    - Related personnel and data processing costs, $200K.

- Modeling (e.g., ongoing at SPAWAR) based upon 1999 activities (specifically design of Phase I A. field work), in preparation for both summer 2000 and summer 2001 field experiments, N/C.

- Target Budget: <u>$2560K</u>.

<u>FY2001</u>

- Tasks:
  - Phase II planning meeting - early calendar year, $50K.
  - Conduct Phase II experiment - spring-early summer.
    - SACLANT vessel, N/C to initiative(?)
    - Shiptime (UNOLS), 3 weeks @ $17K/day, $357K.
    - Equipment (e.g., sound sources), $200K.
  - Personnel/data processing costs (including post-experiment analysis), $750K.
  - Modeling based upon 2000 activities: Phase I ops and STRATAFORM ground-truthing/coring, $500K.
- Target Budget: <u>$1757K</u>.

<u>FY2002</u>

- Tasks:
  - Continued personnel/data processing costs, Phases I and II, $500K.
  - Continued modeling, $400K.
  - Meeting to discuss/disseminate/exchange results, $50K.
  - Publication of results, $100K.
- Target Budget: <u>$1050K</u>.

<u>FY2003</u>

- Tasks:
  - Continued personnel/data processing costs, Phases I and II, $300K.
  - Continued modeling, $300K.
  - Meeting to discuss/disseminate/exchange results, $50K.
  - Publication of results, $100K.
- Target Budget: <u>$750K</u>.

<u>FY2004</u>

- Tasks:
  - Final meeting to exchange data, analyses, etc., $50K.
  - Publication of results, $100K.
  - Data basing, $200K.
- Target Budget: <u>$350K</u>.

Total Budget, FY1999-2004 , <u>$6667K</u>.

SIMRAD ILLUMINATED BATHYMETRY AND THE "CHANNELS" HORIZON

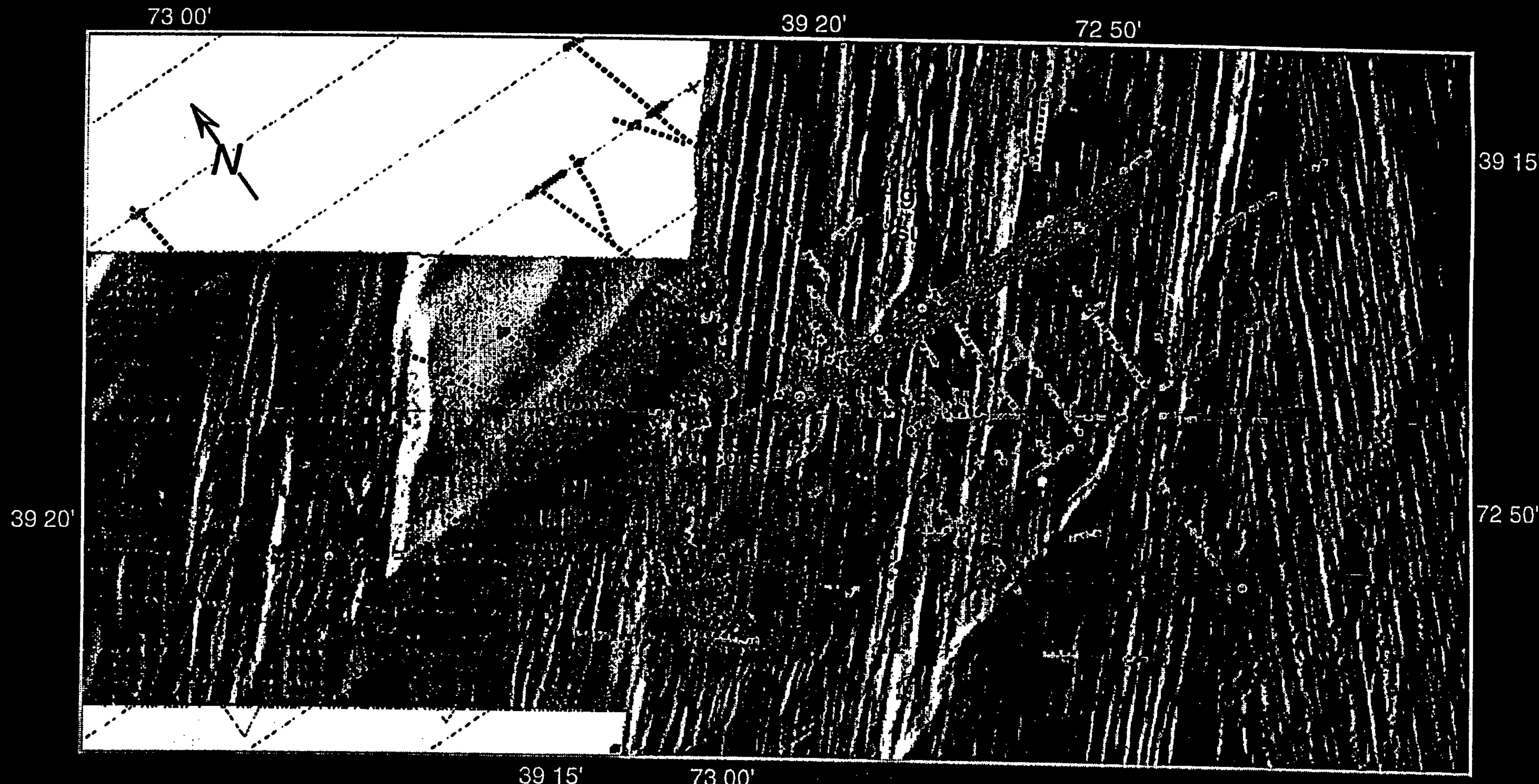
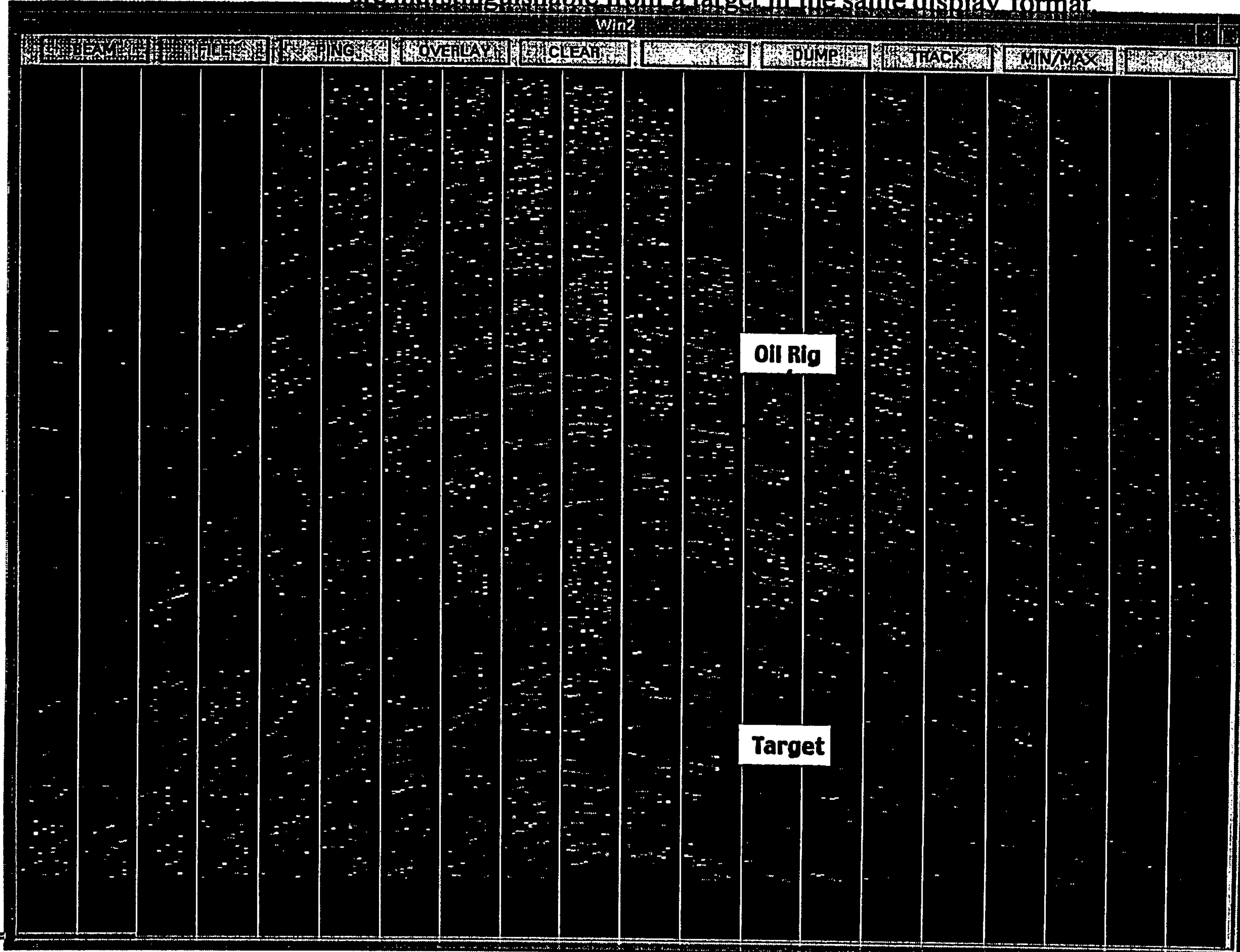


Figure 1. Mapped distribution of shallowly buried subsurface channels, superimposed on Simrad EM1000 swath bathymetry (100% coverage), covering a portion of the New Jersey mid- and outer continental shelf. The long rectangle is a 3D volume, embedded within a grid of E-W and N-S 2D profiles. All seismic profiles were collected using the Huntec DTS boomer system. (Illustration courtesy L. Duncan, UTIG.)

Figure 2. "High clutter" environment sonar display, showing location of a target of interest across a few pings of a multi-ping time history, and the stronger return of an oil rig. Numerous other strong clutter events exist across the display, many of which are indistinguishable from a target in the same display format.



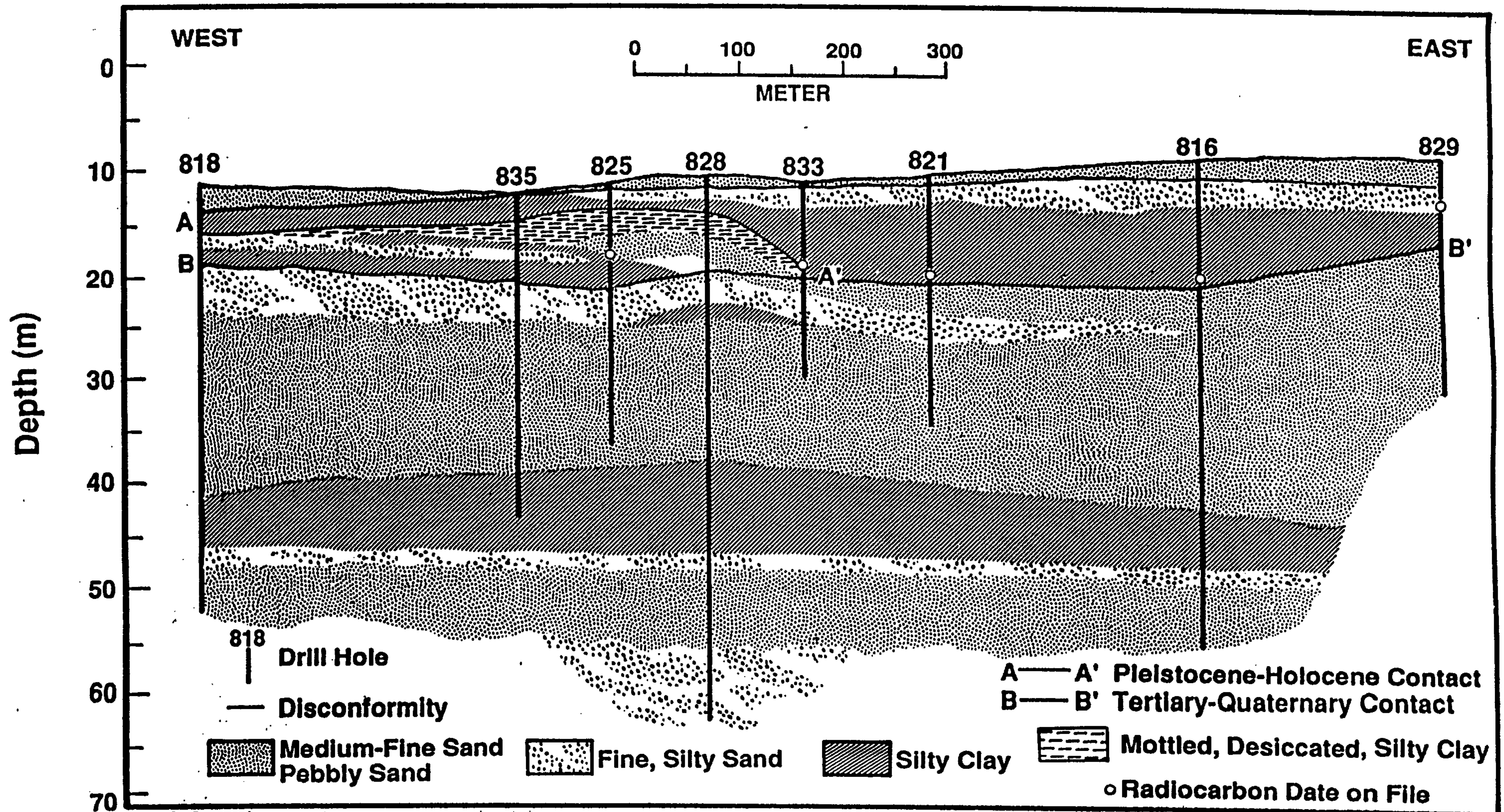


Figure 3. An E-W cross section of a geological profile crossing the Atlantic Generating Site on the New Jersey continental shelf. For each core, the geological data, such as the grain size, density and blow count number (a means of assessing shear strength), are measured. These data are converted to geoacoustic profiles through a proposed algorithm that can also be used in acoustic propagation models. (Figure courtesy M. Badiey.)

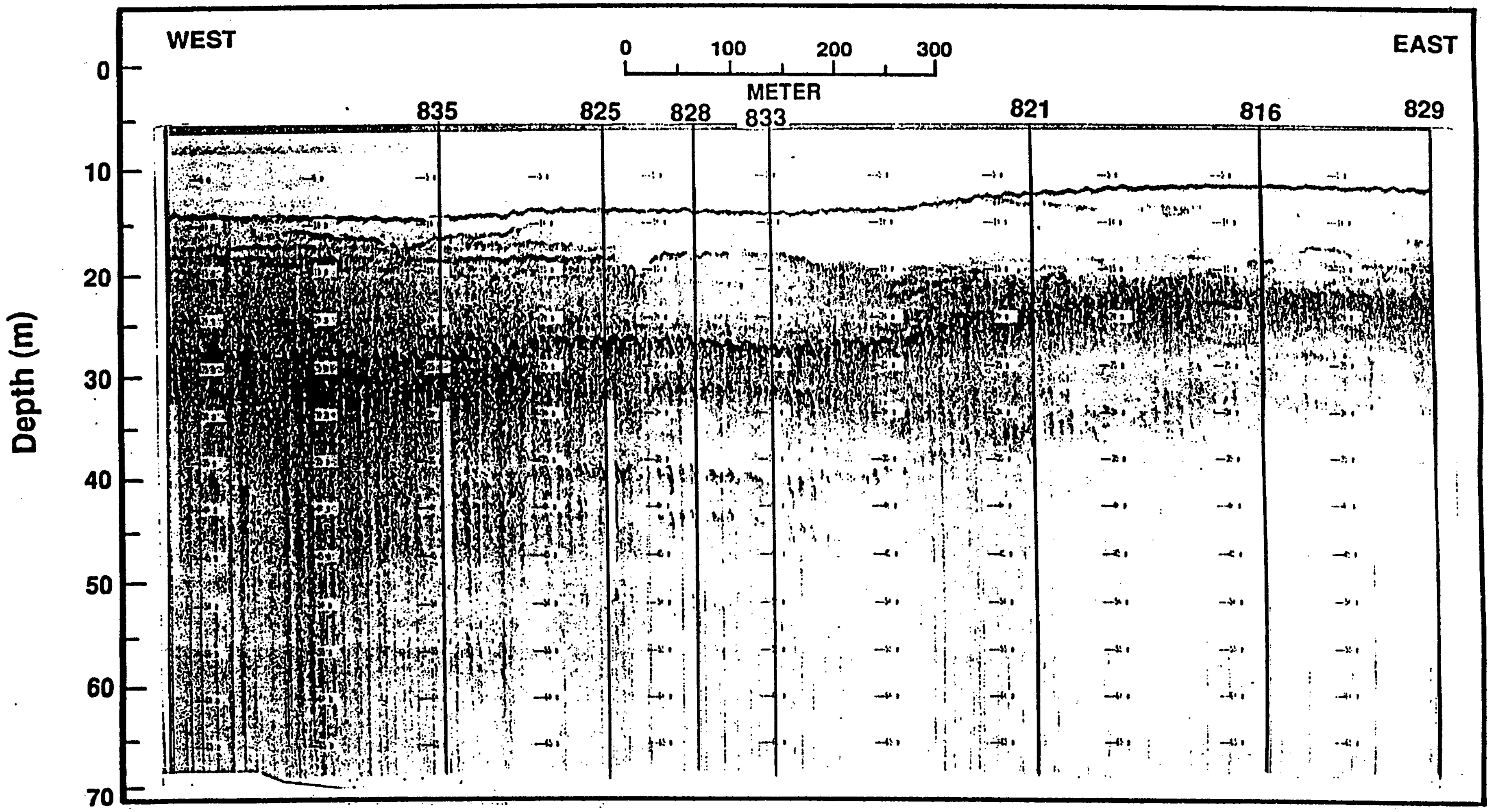


Figure 4. The measured chirp sonar data from the E-W geological cross-section shown in Figure 3. The layers corresponding to the geological interpretations, including subsurface channels, are in excellent agreement with those shown in Figure 3. (Note: The core locations are not exact, due to the difference between GPS locations of the original geological data and DGPS positioning of the chirp profiles collected in 1994.) By using a combination of chirp sonar data and cores, it is possible to obtain range-dependent geoacoustic profiles for input to acoustic propagation models. (Figure courtesy M. Badiey.)

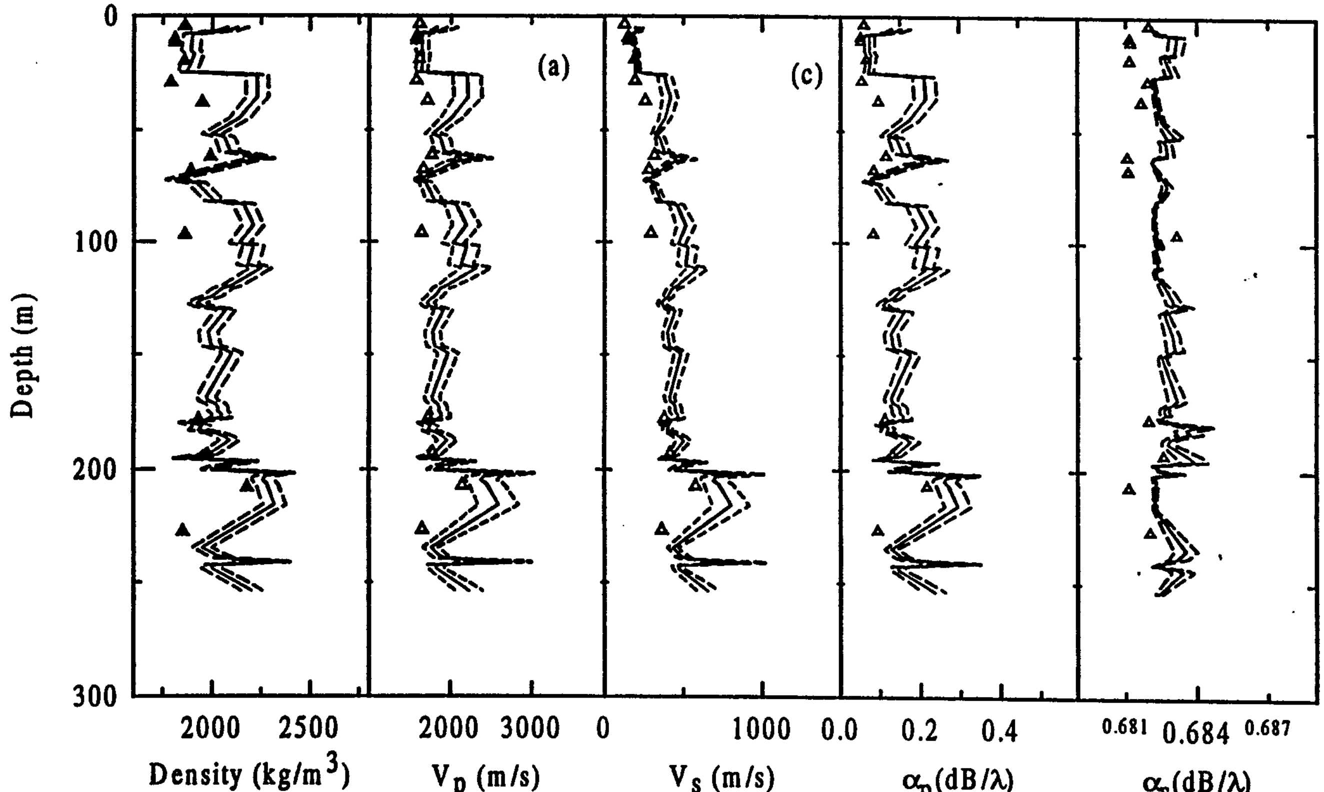


Figure 5. Converted geoacoustic profiles from the geological information available for AMCOR 6010 on the New Jersey continental shelf (see Figures 3 and 4). The five geoacoustic parameters, namely the density, compressional and shear sound speed profiles, and their corresponding attenuation profiles, are shown compared with the field-collected data.

Geologic Clutter Workshop Participants
June 29-30, 1999

Dr. James A. Austin, Jr.
Institute for Geophysics
The University of Texas at Austin
4412 Spicewood Springs Road, Bldg. 600
Austin, TX 78759-8500
Tel: (512) 471-0450
Fax: (512) 471-8844
jamie@utig.ig.utexas.edu

Dr. Mohsen Badiey
College of Marine Studies
University of Delaware
Newark, DE 19716
Tel: (302) 831-3687
Fax: (302) 831-3302
badiey@udel.edu

Dr. Arthur Baggeroer
Department of Ocean Engineering
Massachusetts Institute of Technology
77 Massachusetts Avenue, Room 5-204
Cambridge, MA 02139
Tel: (617) 253-4336
Fax: (617) 253-2350
abb@arctic.mit.edu

Dr. David Drumheller
Naval Research Laboratory
Code 7144
Washington, DC 20375
Tel: (202) 404-4815
Fax: (202) 404-7732

Dr. Roger Gauss
Naval Research Laboratory
Acoustics Division
Code 7144
Washington, DC 20375
Tel: (202) 767-3524
Fax: (202) 404-7732
roger.gauss@nrl.navy.mil

Dr. John A. Goff
Institute for Geophysics
The University of Texas at Austin
4412 Spicewood Springs Road, Bldg. 600
Austin, TX 78759-8500
Tel: (512) 471-0476
Fax: (512) 471-0999
goff@utig.ig.utexas.edu

Dr. Darrell Jackson
Applied Physics Laboratory
Department of Electrical Engineering
University of Washington
1013 NE 40th Street
Seattle, WA 98105
Tel: (206) 543-1359
Fax: (206) 543-6785
drj@apl.washington.edu

Dr. Ashok K. Kalra
Naval Oceanographic Office
1002 Balch Boulevard
Stennis Space Center, MS 39522-5001
Tel: (228) 688-4084
Fax: (228) 688-5485
kalraa@navo.navy.mil

Dr. Joseph H. Kravitz
Office of Naval Research
Code 322GG, Ballston Tower One
800 North Quincy Street
Arlington, VA 22217-5660
Tel: (703) 696-4070
Fax: (703) 696-2710
kravitj@onr.navy.mil

Mr. Jim Lockwood
SPAWAR Systems Center
Code 7102
San Diego, CA 92152-6146
Tel: (619) 553-2057
Fax: (619) 553-2049
lockwood@spawar.navy.mil

Geologic Clutter Workshop Participants
June 29-30, 1999

Dr. Nick Makris
Department of Ocean Engineering
Massachusetts Institute of Technology
77 Massachusetts Ave., Rm. 5-222
Cambridge, MA 02139
Tel: (617) 258-6104
Fax: (617) 253-2350
makris@mit.edu

Mr. John Preston
Applied Research Laboratory
The Penn State University
P.O. Box 30
North Atherton Street
State College, PA 16803
Tel: (814) 863-1310
Fax: (814) 8863-8783
preston@ciao.arl.psu.edu

Dr. Steven Schock
Department of Ocean Engineering
Florida Atlantic University
Boca Raton, FL 33431
Tel: (561) 297-3442
Fax: (561) 297-3885
schock@oe.fau.edu

Dr. Jeff Simmen
Office of Naval Research
Code 3210A, Ballston Tower One
800 North Quincy Street
Arlington, VA 22217-5660
simmenj@onr.navy.mil

Dr. Michael Sundvik
Naval Undersea Warfare Center
Code 3113
Newport, RI 02841-1708
Tel: (401) 832-8680
sundvikmt@npt.nuwc.navy.mil

Dr. James Syvitski
Institute of Arctic and Alpine Research
University of Colorado at Boulder
Campus Box 450
Boulder, CO 80309
Tel: (303) 492-7909
Fax: (303) 492-3287
james.syvitski@colorado.edu

ATTACHMENT NUMBER 1

REPORTS AND REPORT DISTRIBUTION

REPORTS DISTRIBUTION	
ADDRESSEE	NUMBER OF COPIES
Office of Naval Research Program Officer Joseph H. Kravitz ONR Code: 322GG Ballston Tower One 800 North Quincy Street Arlington, Virginia 22217-5660	4 copies of proceedings w/(SF-298)
Grant Administrator OFFICE OF NAVAL RESEARCH REGIONAL OFFICE SAN DIEGO 4520 EXECUTIVE DRIVE SUITE 300 SAN DIEGO, CA 92121-3019	Copy of cover letter to DTIC and SF-298
Defense Technical Information Center 8725 John J. Kingman Road STE 0944 Ft. Belvoir, Virginia 22060-6218	1 copy of proceedings w/(SF-298)