High-Resolution Marine Seismic
Reflection Data Acquisition
Using an Engineering Seismograph

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**HIGH-RESOLUTION MARINE SEISMIC REFLECTION DATA
ACQUISITION USING AN ENGINEERING SEISMOGRAPH**

**MINERALS MANAGEMENT SERVICE YEAR 9
FINAL TECHNICAL REPORT, 1994
AGREEMENT NUMBER 14-12-0001-30666**

by

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In addition to this Technical report, the research program has resulted in the following presentations (included following this report) before professional societies:

Waldner, J. S., Sheridan, R. E., Hall, D. W., and Ashley, G. M., 1994, High-resolution marine seismic reflection data acquisition using an engineering seismograph: Symposium on the Application of Geophysics to Engineering and Environmental Problems, Environmental and Engineering Geophysical Society, March 27-31, Boston, Massachusetts.

Waldner, J. S. Sheridan, R. E., Carey, J. S., Ashley, G. M. and Henne, R. G. Jr., 1993, Digital continuous seismic reflection profiles of New Jersey inner shelf sand ridges: The Geological Society of America 28th Annual Northeast Section Annual Meeting March 22-24, Burlington, Vermont.

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HIGH-RESOLUTION MARINE SEISMIC REFLECTION DATA ACQUISITION USING AN ENGINEERING SEISMOGRAPH

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ABSTRACT

A digital single-channel seismic reflection system was developed to acquire continuous profiling data by interfacing a conventional analog system with a land-based digital signal-enhancement engineering seismograph. Digital profiles are enhanced by trace static correction, deconvolution, automatic gain scaling, weighted horizontal stacking and digital filtering. Problems common to analog data, such as wave-motion effects of surface sources, water-bottom reverberation, multiple reflections, and bubble-pulse width can be addressed by the processing. The fast firing rate for analog records is maintained while a trigger-divider sends a slower trigger rate to the digital seismograph. An auto-save feature with an automatic roll-along switch groups adjacent traces to files, eliminating system limitations of the mass-storage device.

The digital data were collected to map sand ridges of the inner continental shelf off New Jersey for beach sand replenishment surveys. The seismic tracklines are correlated to vibracores and known geologic stratigraphy. The digital data exhibit reflections from layers less than 1 meter thick. Synthetic seismograms constructed from the vibracore information show these internal reflectors are caused by shelly gravel/medium sand interfaces. Global Positioning System (GPS) was used to plot real-time position as well as obtain a navigational accuracy within 10 meters. The combination of the analog system with the land-based seismograph offers a less expensive technique for digital acquisition and processing. This provides improved results over older analog data.

ACKNOWLEDGMENT

This research was supported by the Minerals Management Service, U. S. Department of the Interior, under MMS Agreement Numbers 14-12-0001-30666 and 14-35-0001-30643. The authors gratefully acknowledge the assistance of the members of the New Jersey Geological Survey; Rutgers University, Department of Geological Sciences; and the Bureau of Marine Water Classification, Department of Environmental Protection and Energy, who assisted in the marine surveys.

INTRODUCTION

For the past two years the New Jersey Geological Survey and Rutgers University, Department of Geological Sciences, have conducted digital high-resolution single-channel

marine seismic surveys using a conventional analog equipment paired with a land-based engineering seismograph. This purpose is part of an ongoing project to map marine sediments for sand deposits that are suitable for beach replenishment. The system is to capitalize on the processing and archival capabilities of digital data.

Although analog seismic equipment may be adequate for many objectives, including surveys for beach sand resources, for detailed or large surveys, analog paper records and tapes quickly become a data-management nightmare. Post-acquisition processing is commonly limited to tape playback through the analog unit. Previous investigators have sought to minimize data-quality degradation experienced with analog recording by utilizing digital analog tape (DAT) for subsequent analog playback or digital conversion. Although DAT greatly improves data-record quality, the authors feel that current digital engineering seismographs have analog-to-digital conversion, dynamic-range, and signal sampling advantages, compatible with seismic sources in the less-than-1.2-kilohertz range.

The enhanced digital system had to meet certain minimal criteria to prove its superiority to an analog survey program. These are:

- a) low incremental cost compared to a stand-alone analog unit
- b) ease of implementation using off-the-shelf components
- c) maintenance of a high-resolution capability with the seismic source
- d) conventional data-storage formats (SEG1, SEG2 or SEG Y)
- e) suitability to available digital processing software
- f) data transfer and storage on a microcomputer
- g) a suitable method for correlating data to geographic position

DATA ACQUISITION SYSTEM

The analog system is an ORE Geopulse™ system in which a towed catamaran with a magnetorestrictive diaphragm having a peak frequency of about 1.0 kilohertz is the seismic source. The power supply (Model 5420A) provides several energy levels of 105, 175, 280, 350 and 455 joules. A Geopulse™ receiver (Model 5210A) and EPC graphic recorder, control the firing rate, frequency filtering, gain scaling, before plotting on electrosensitive paper. A digitizing dual trace oscilloscope (Hewlett Packard Model 54200A/D) is used to monitor the incoming raw and filtered signal.

The digital system receiver is a Bison Instruments 9024™ 24-channel engineering seismograph. Analog-to-digital conversion is 16-bit with digital instantaneous floating point. Wave noise (a low-frequency high-energy signal) requires the conditioning of the raw signal by the analog-receiver low-cut frequency filters before entering the first channel of the digital seismograph. Digital filters on the digital seismograph are, therefore, selected with due regard to the analog filters to minimize signal aliasing. The Bison is equipped with an auto-save feature where data are routed to internal storage after a pre-set number of enhancements. For the marine survey each shotpoint is saved without signal enhancement. Internal data storage is an 80-megabyte hard disk.

A trigger-divider and automatic roll-along switch are used to overcome digital recording and storage problems. A trigger-divider sends a slower trigger rate to the digital seismograph, while maintaining the fast firing-rate for analog records. The slower digital trigger-rate serves three purposes. First, it adapts the firing rate normally used by analog units which is too fast (often 2-5 triggers per second) for the cycle time of the engineering seismograph; second, it maintains output of an analog paper copy for cursory interpretation and overall quality control; and third, it reduces the amount of digital data collected to a manageable but representative size. An automatic roll-along switch (developed by Bison Instruments) by grouping adjacent traces to files, overcomes limitations of the seismograph's mass-storage device and the micro-computer. The 12-channel roll-along switches the single channel input to the next trace after each trace-sampling cycle. With the auto-save feature set to 12 enhancements before saving, the roll-along groups 12 sequential traces to a single file. The system is limited to 12 instead of 24 channel files so that the auto-save cycle time is shorter than the digital firing-rate.

The digital operating system limits downloading to 999 files or fewer, even though, a larger number can be saved by the seismograph. In addition, download time for hundreds of small files to a microcomputer increases geometrically to unfeasible limits. For most survey situations, at 12 traces per file, the 80-megabyte hard disk can accommodate nearly 12,000 recorded traces. This is enough for a single day of data collection, permitting downloading overnight. For example, with an analog firing rate of 3 shots-per-second, and a trigger-divider ratio of 10:1, approximately 11 hours of continuous digital recording is possible.

Survey positioning via the Global Positioning System (GPS) enables one to plot real-time position and to obtain navigational accuracy within 10 meters following processing. The seismic data is correlated to the GPS data by synchronization of the seismograph clock to the GPS; thereby, matching seismic data file-header time-tags to geodetic coordinates.

FIELD EXAMPLE - Beach-Sand-Replenishment Sand Ridges

The purpose of the initial year's survey was to examine the operational effectiveness of the digital seismic system in previously studied areas. The surveys focused on sand ridge deposits, which are linear features of shallow topographic relief 3-10 meters trending south-west-northeast along the inner continental shelf off New Jersey. These concentrated sand deposits are commonly the most suitable economical sources of sand for beach replenishment.

A digital survey trackline traversed a shore detached ridge off Long Beach Island, (figures 1a and 1b) in an area previously studied by Ashley and others, 1991 and Wellner and others, 1993. Synthetic seismograms constructed from Vibracores of 1-6 meters depth (Esler, 1992) were correlated to the seismic stratigraphic data.

The digital seismic data were processed using the Eavesdropper™ software (Kansas Geological Survey, 1993). Processing of the section shown in figure 2 followed routines using trace static correction, deconvolution, trace normalization, weighted horizontal stacking and digital filtering. Unfortunately, processing failed to minimize the effects of water bottom reverberation, caused primarily by the use of the intermediate energy output of 280 joules for the Geopulse™ in shallow waters. This problem was corrected in subsequent surveys by reducing the Geopulse™ output to 105 joules.

Figure 1. A. Study area location map within mid Atlantic bight, from Ashley, 1991. **B.** Bathymetric map of the study area showing important geomorphic features and location of digital seismic section shown in figure 2. Modified from Ashley, 1991. Contour interval = 2 meters. Depth is in meters from sea level NGVD of 1929.

B.

Three major traceable unconformities (R1, R2 and R3) in the shallow subsurface are shown in the seismic section (figure 2). The digital data also exhibit reflections from layers less than 1 meter thick. Synthetic seismograms constructed from the vibrocore information show that these internal reflectors are caused by shelly gravel/medium sand interfaces. Internal reflections of the detached sand ridge downlap onto the erosional surface, R3. This indicates that the shore ridge is a depositional feature. At the landward (northwest) edge of the section, steeply dipping internal reflectors between R1 and R2 are interpreted as mid-Wisconsin (approximately 55,000 years ago) barrier-island shoreface deposits.

RESULTS AND CONCLUSIONS

The New Jersey Geological Survey and Rutgers University, Department of Geological Sciences have collected more than 250 line-kilometers of digital seismic data utilizing the digital system. Analog and digital records were used for processing and for interpretation. These surveys, combined with pre-existing data, have enabled us to identify nearly 23 million cubic meters of sand for possible use in restructuring damaged shoreline and beaches along the New Jersey coast. The digital data have proven to be advantageous in both operational cost, data management, geographic accuracy, and enhanced data quality.

DISCLAIMER

The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either express or implied, of the U. S. Government.

The use of trade, brand, or commercial names is for identification purposes only and does not indicate endorsement by the authors or their affiliated agencies.

CITED REFERENCES

- Ashley, G. M., Wellner, R. W., Esker, D., and Sheridan, R. E., 1991, Clastic sequences developed during late quaternary glacio-eustatic sea level fluctuations on a passive margin: Example from the inner continental shelf near Barnegat Inlet, New Jersey: Geological Society of America Bulletin v. 103, p. 1607-1621, 13 figs., 1 table.
- Esker, Dominic, 1992, Synthetic seismograms from vibrocores: a tool for correlating the seismic record to the sediment record of Barnegat Inlet, New Jersey: unpublished M.S. thesis Rutgers University, New Brunswick, NJ 198 p.
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- Wellner, R. W., Ashley, G. M., and Sheridan, R. E., 1993, Seismic stratigraphic evidence for a submerged middle Wisconsin barrier: Implications for sea-level history: Geology, v. 21, p. 109-112, p. 109-112, 4 figs.

A.
NW

SE

B.

Figure 2. Digital marine seismic section, land to left ocean to right **A.** Processed section across detached sand ridge. Horizontal divisions are every 10 milliseconds. **B.** Interpreted section (from cores 9 and 10) showing southeast dipping shallow reflections. Internal reflectors of the sand ridge and steeply dipping barrier island shoreface deposits also shown.

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March 22-24, 1993
Sheraton Hotel and Conference Center
Burlington, Vermont

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5 Kenneth Munkins*: LARGE-SCALE, WIND-DRIVEN MOTION IN LAKE CHAMPLAIN [006022]	9:40 A
BREAK	10:00 A
6 J. Saylor*, T. O. Manley, P. L. Manley, J. Miller: PHYSICAL PROCESSES DRIVING HIGH-SPEED CURRENTS IN LAKE CHAMPLAIN BOTTOM WATER [031261]	10:20 A
7 P. L. Manley*, T. O. Manley: SEDIMENT-CURRENT INTERACTIONS AT VALCOUR ISLAND, LAKE CHAMPLAIN--A CASE OF HELICAL FLOW IN THE BOTTOM BOUNDARY LAYER [002979]	10:40 A
8 Ellen L. McCray*, John W. King: AN HISTORICAL ASSESSMENT OF TRACE METAL ACCUMULATION IN LAKE CHAMPLAIN, VERMONT [001635]	11:00 A
9 R. S. Haupt*, D. W. Folger: PAPER PLANT EFFLUENT IN SEDIMENTS OF SOUTHERN LAKE CHAMPLAIN [004170]	11:20 A
FINAL REMARKS	11:40 A

QUATERNARY GEOLOGY AND GEOMORPHOLOGY

Sheraton Conference Center, Emerald Grand Ballroom, Salon 2, 8:00 A.M.

Larry Ward and Thomas Lowell, Presiding

1 Robert E. Morency*: A BURIED MARINE DEPOSITIONAL SEQUENCE (PRESUMPTOT PM.) N. OF THE MARINE LIMIT, WATERBORO, MAINE [028708]	8:00 A
2 Christopher C. Dorion*: A CHRONOLOGY OF DEGLACIATION AND ACCOMPANYING MARINE TRANSGRESSION IN MAINE [004177]	8:20 A
3 Larry G. Ward*: QUATERNARY SEDIMENTATION IN A TIDE-DOMINATED ESTUARY, NORTHERN NEW ENGLAND [026744]	8:40 A
4 J. Kucwicz, Jr.*, J. Kbert, C. Rasquin, R. Sherman, R. Methaway, J. Gardner, K. Milunich, J. Weber, T. Wohlford, J. Franz, S. Brillion: UNUSUAL CONFIGURATION OF THE DEVONIAN-PLEISTOCENE UNCONFORMITY IN THE SUSQUEHANNA VALLEY, ONEONTA, NEW YORK: EVIDENCE FOR A SUBGLACIAL MELT-WATER INLET TO GLACIAL LAKE OTEGO [019669]	9:00 A
5 Eric Small*, David Desimone: ASYNCHRONOUS ICE LOBE RETREAT AND GLACIAL LAKE BASCOM: DEGLACIATION OF THE HOOSIC AND VERMONT VALLEYS, SOUTHWESTERN VERMONT [028899]	9:20 A
6 Thomas V. Lowell*: THE LATE WISCONSIN BOUNDARY OF THE SCIOTO SUBLOBE NEAR CHILLICOTHE, OHIO [003407]	9:40 A
BREAK	10:00 A
7 W. Roland Gehrels*, Daniel F. Belknap, Joseph T. Kelley, Bin Gong, Bryan R. Pearce: RELATIVE SEA-LEVEL TRENDS ALONG THE COAST OF MAINE DURING THE PAST 5000 14C YEARS [026788]	10:20 A
8 D. M. Covello*, K. A. Knott, P. R. Pinet, C. E. McClennan: EROSIONAL DYNAMICS AND MORPHOLOGICAL ANALYSIS ALONG THE SOUTHEASTERN LAKE ONTARIO SHORELINE, NEW YORK STATE [029412]	10:40 A
9 Matthew Cohn*, R. Craig Kochel: THE RELATIVE ROLE OF GEOMORPHIC PROCESSES IN STORM RECOVERY OF WASHOVER SITES ON THE VIRGINIA BARRIER ISLANDS [031195]	11:00 A
10 Katherine A. Kowalski*: INFLUENCE OF BARRIER ISLAND STRATIGRAPHY AND BATHYMETRY ON SHORELINE CHANGE [031076]	11:20 A
11 Lawrence W. Gatto*: BANK EROSION IN COLD REGIONS [025908]	11:40 A

POSTER SESSION V: ENVIRONMENTAL GEOLOGY, MARINE GEOLOGY, SEDIMENTARY ROCKS, AND QUATERNARY GEOLOGY
Sheraton Convention Center, Lake Champlain Exhibition Hall, 8:00 A.M. - 12:00 Noon

Authors will be present from 9:00 to 11:00

ENVIRONMENTAL GEOLOGY

Peter Smith*, William Goodman, Ronald Cole, Laura Abbott: USE OF PENETRATIVE INVESTIGATIONS AND PUMPING TEST DATA TO REVISE LARGE SCALE MAPS OF SUFFICIAL AQUIFERS IN NORTHERN CATTARAUGUS COUNTY, NEW YORK [020188]	Booth 1
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Steven J. Stokowski, Jr.*: GEOLOGY OF CONCRETE AGGREGATE QUALITY IN NEW ENGLAND [022700]	Booth 2
Joshua B. Holden*, Anne I. Veeger: THE EFFECT OF HUMAN ACTIVITIES ON THE QUALITY OF GROUND WATER IN THE CHIPUKET AQUIFER, RHODE ISLAND [028136]	Booth 3
William T. Frederick*, Thomas X. Grasso, Jr.: SECONDARY POROSITY IN A TRANSIENT VADOSE ZONE [026043]	Booth 4
Ronald Cole*, William Goodman, Peter Smith, Donald Cadwell: SEDIMENTOLOGICAL ANALYSIS OF A PLEISTOCENE VALLEY-FILL: USE OF PENETRATIVE INVESTIGATIONS TO REVISE REGIONAL MAPS OF SURFICIAL GEOLOGY IN NORTHERN CATTARAUGUS, NEW YORK [020189]	Booth 5
David D. Gammons*: SPONTANEOUS POTENTIAL (SP) GEOPHYSICAL METHOD--APPLICATION TO GROUND-WATER MOVEMENT IN A GLACIAL SEDIMENT--PENIKESSE ISLAND, MASSACHUSETTS [024579]	Booth 6
Kelly C. Cloyd*, Patrick W. Concannon: LANDFILL SITING IN NEW YORK: CASE STUDIES CONFIRMING THE IMPORTANCE OF SITE-SPECIFIC HYDROGEOLOGIC INVESTIGATIONS [019675]	Booth 7
Kenneth G. Johnson*: APPROPRIATE, AFFORDABLE ASSESSMENT OF GEOENVIRONMENTAL FACTORS CONSTRAINING SUBURBAN EXPANSION AT THE NORTHEASTERN MARGIN OF THE CAPITAL DISTRICT, NEW YORK STATE [031587]	Booth 8

MARINE GEOLOGY

Walter A. Barnhardt*, Daniel F. Belknap, Joseph T. Kelley, Steven M. Dickson: SURFICIAL GEOLOGY OF THE KENNEBEC RIVER PALEODELTA: A PRODUCT OF PLEISTOCENE DEPOSITION, MODIFICATION BY HOLOCENE TRANSGRESSION, AND MODERN SEDIMENT REWORKING [027508]	Booth 9
D. C. Barber*, D. F. Belknap, J. T. Kelley: BARRIER BEACH EVOLUTION IN SOUTHWESTERN MAINE: CONSTRAINING A SEDIMENT BUDGET BY ANALYZING DEPOSITIONAL PRODUCTS IN SAGO BAY [004176]	Booth 10
Jeffrey S. Waldner*, Robert E. Sheridan, John S. Carey, Gail M. Ashley, Richard G. Henne, Jr.: DIGITAL CONTINUOUS SEISMIC REFLECTION PROFILES OF NEW JERSEY INNER SHELF SAND RIDGES [032779]	Booth 11
Sytse van Kesteren*, Duncan M. Fitzgerald, L. Kenneth Fink, Jr.: DEVELOPMENT OF THE BARRIER SYSTEM AT FERRY BEACH, MAINE--EVIDENCE OF TRANSGRESSIVE AND REGRESSIVE PHASES [029193] ...	Booth 12
Stephen M. Dickson*, Joseph T. Kelley, Daniel F. Belknap: STORM-INDUCED SAND TRANSPORT AND BEDFORM GENESIS AT BEACH AND SHOREFACE ENVIRONMENTS OF THE MAINE COAST [004012]	Booth 13

SEDIMENTARY ROCKS

Norman M. Gillmeister*, Dale A. Springer: "THE HAYSTACKS": AN UNUSUAL SOFT-SEDIMENT DEFORMATION FEATURE IN THE UPPER DEVONIAN OF NORTHEASTERN PENNSYLVANIA [024706]	Booth 14
L. J. Poppe*, C. W. Poag: MESOZOIC STRATIGRAPHY AND PALEOENVIRONMENTS OF THE EXXON 975-1 WELL, GEORGES BANK BASIN, U.S. NORTH ATLANTIC OUTER CONTINENTAL SHELF [001639]	Booth 15
D. J. Mauriello*, M. W. Ketterer: CORRELATION OF HIERARCHAL UPPER SILURIAN STACKING PATTERNS GENERATED BY MILANKOVITCH ORBITAL FORCING [031236]	Booth 16

QUATERNARY GEOLOGY

P. M. Millette*: PLANT COMMUNITIES AS INDICATORS OF SALT MARSH HYDROLOGY? A STUDY AT GOOSE FARE BROOK, SAGO, MAINE [027510]	Booth 17
Denise R. Muriceak*: PALEOHYDRAULIC INTERPRETATION AND MORPHOLOGIC RECONSTRUCTION OF THE NORTHERN RIO GRANDE RIVER, COLORADO [002799]	Booth 18
Duncan M. Fitzgerald*, Pamela A. Manthorp, Ching-Euei Kuo, Sytse Van Kesteren, L. Kenneth Fink, Jr., Joseph T. Kelley: ESTUARINE CIRCULATION AND SEDIMENT TRANSPORT TRENDS IN THE LOWER SAGO RIVER [029192]	Booth 19

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Complete all sections ① through ⑨ below.

① TYPE ABSTRACT COMPLETELY WITHIN THE BLUE LINES BELOW. (10 point type minimum)

No 32779

DIGITAL CONTINUOUS SEISMIC REFLECTION PROFILES OF NEW JERSEY INNER SHELF SAND RIDGES

WALDNER, Jeffrey S., N.J. Geological Survey, CN427, Trenton, NJ 08625; SHERIDAN, Robert E., CAREY, John S., ASHLEY, Gail M., Dept. of Geological Sciences, Rutgers University, New Brunswick, New Jersey, 08903; HENNE, Richard, G. Jr., N.J. Geological Survey.

Digital continuous profiling seismic reflection data were collected along three sand ridges of the inner continental shelf off New Jersey in August 1992. The acquisition system consisted of a conventional analog Geopulse™ system interfaced with a land-based digital signal-enhancement engineering seismograph. The Global Positioning System (GPS) was used to obtain a navigational accuracy within 5 meters after processing. The raw data exhibit seismic reflections from layers less than 1 meter thick. The seismic tracklines were correlated to Vibracores™ and known geologic stratigraphy. The data show early to late Holocene depositional sequences overlying a mid-Wisconsinan barrier system located at depths of 20 meters. The sand ridges occur as constructive features above an unconformity in an asymmetrical profile where cross bedding reflections downlap on the unconformity and dip gently seaward. Synthetic seismograms constructed from Vibracores™ show that these internal reflections are caused by interfaces between shelly gravel and medium sand. Digital profiles show processing enhancements including trace static correction, deconvolution, automatic gain scaling, weighted horizontal stacking and digital filtering in addition to color panels. Problems common to analog data, such as wave motion effects of surface sources, water bottom reverberation, multiple reflections, and bubble pulse width, are addressed by digital processing. The combination of the analog system with the land-based seismograph offers a less expensive technique for digital acquisition and processing, thus providing improved results over older analog data.

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A-3

starting near the contact of the country rock and going into the metagabbro for a distance of 65 feet. The country rock contains an assemblage of alkali feldspar, plagioclase, quartz, biotite, apatite and magnetite. The metagabbro contains an assemblage of plagioclase, hornblende, clinopyroxene, biotite, quartz, sphene, apatite and opaques. Chemical data show a decrease of SiO_2 and K_2O from the edge of the metagabbro towards the center, and an increase in CaO , Fe_2O_3 , MgO , TiO_2 , P_2O_5 , Ni , V , and Cr_2O_3 . The Al_2O_3 and Na_2O content remain nearly constant. Hand samples stained with sodium cobaltinitrite also reflect decreasing K_2O towards the core of the body. These chemical gradations may be due to metasomatism, assimilation of country rock or true compositional zoning during crystallization of an alkali-rich gabbro.

Nº 3795

THE SUMMIT, NEW YORK EARTHQUAKE OF JUNE 17, 1991

WALCOTT, Jessica and REVETTA, Frank, Department of Geology, Potsdam College of the State University of New York, Potsdam, N.Y. 13676.

On June 17, 1991 an earthquake of magnitude 4.0 shook southern New York. The epicenter was located at $42^\circ 35.49' \text{N}$ Latitude and $74^\circ 38.22' \text{W}$. Longitude by Lamont-Doherty Geological Observatory. This location is 40 miles southwest of Albany near the town of Summit, N.Y. The earthquake was felt strongly in the Albany-Syracuse area, southward in Rockland and Westchester counties, and westward in the Rochester area. The earthquake was unusual in a sense since it occurred in the Catskill Mountains, an aseismic area where relatively few earthquakes occur. Also the epicenter was located just 18 miles northwest of the Gilboa Dam however no damage was reported at the dam.

The focal depth of the event was reported as 13 kms. This focal depth puts the hypocenter well within the Precambrian rocks since the elevation of the Precambrian basement is ~3kms in the epicentral region. The epicenter is located near a north-south trending horst structure in the Cambro-Ordovician and Precambrian rocks and along a series of northeast trending topographic linear features shown on a brittle fracture map of the area. The location of the epicenter and focal depth of 13 kms suggest the horst structure or northeast fractures may have been reactivated by stresses in the area to produce the earthquake and that the structure extends to a greater depth of possibly 10 kms. An historical earthquake search indicates that at least 9 other earthquakes occurred in the area since 1877. Two of the epicenters of these earthquakes are aligned along the horst structure.

Nº 32779

DIGITAL CONTINUOUS SEISMIC REFLECTION PROFILES OF NEW JERSEY INNER SHELF SAND RIDGES

WALDNER, Jeffrey S., N.J. Geological Survey, CN427, Trenton, NJ 08625; SHERIDAN, Robert E., CAREY, John S., ASHLEY, Gail M., Dept. of Geological Sciences, Rutgers University, New Brunswick, New Jersey, 08903; HENNE, Richard, G. Jr., N.J. Geological Survey

Digital continuous profiling seismic reflection data were collected along three sand ridges of the inner continental shelf off New Jersey in August 1992. The acquisition system consisted of a conventional analog Geopulse™ system interfaced with a land-based digital signal-enhancement engineering seismograph. The Global Positioning System (GPS) was used to obtain a navigational accuracy within 5 meters after processing. The raw data exhibit seismic reflections from layers less than 1 meter thick. The seismic tracklines were correlated to Vibrocores™ and known geologic stratigraphy. The data show early to late Holocene depositional sequences overlying a mid-Wisconsinan barrier system located at depths of 20 meters. The sand ridges occur as constructive features above an unconformity in an asymmetrical profile where cross bedding reflections downlap on the unconformity and dip gently seaward. Synthetic seismograms constructed from Vibrocores™ show that these internal reflections are caused by interfaces between shelly gravel and medium sand. Digital profiles show processing enhancements including trace static correction, deconvolution, automatic gain scaling, weighted horizontal stacking and digital filtering in addition to color panels. Problems common to analog data, such as wave motion effects of surface sources, water bottom reverberation, multiple reflections, and bubble pulse width, are addressed by digital processing. The combination of the analog system with the land-based seismograph offers a less expensive technique for digital acquisition and processing, thus providing improved results over older analog data.

Nº 4413

AN ACADIAN ALLOCHTHON IN THE HUMBER ZONE OF WESTERN NEWFOUNDLAND. IMPLICATIONS OF INDUSTRY AND LITHOPROBE SEISMIC PROFILES

WALDRON, J. W. F., Geology Department, Saint Mary's University, Halifax, Nova Scotia, B3H 3C3 Canada, and STOCKMAL, G. S., Institute of Sedimentary and Petroleum Geology, 3033-33rd St. N.W. Calgary, Alberta, Canada, T2L 2A7.

In the Humber Zone of western Newfoundland, Grenville age basement rocks are exposed in the Long Range and Indian Head inliers. They are unconformably overlain by a Cambrian-Ordovician shelf succession, above which Taconian allochthons were emplaced in Middle

Ordovician time. At the western edge of the Humber Zone, post-Taconian, pre-Acadian strata of the Long Point - Clam Bank succession are deformed in a west-facing monoclinel structure, visible in industry seismic profiles and exposed at Port au Port Peninsula. This structure is interpreted as a triangle zone within which the exposed shelf succession and overlying Taconian allochthon were transported westward in Acadian deformation.

Canadian LITHOPROBE seismic profiles cross the Humber Zone near Stephenville (line 12) and east of the Bay of Islands (lines 1-4). Line 12 shows subhorizontal reflectors beneath the Indian Head massif and continuing east between 3 and 4.5 s two-way travel time. These are correlated with gently east-dipping reflectors beneath the triangle zone offshore and interpreted as the autochthonous shelf succession. The overlying assemblage of thrust sheets, including the outcropping basement and shelf succession, is termed the Port au Port Allochthon.

Lines 1 to 3 cross the shelf succession and Taconian allochthonous units south of the Long Range Grenville massif. Subhorizontal reflectors, again interpreted as autochthonous platform and/or basement, are well imaged west of Deer Lake between 2 and 4 seconds two-way travel time. Discontinuous reflections can be traced farther west into the Bay of Islands area.

These observations suggest that the southern Long Range and its cover are also allochthonous, transported at least 30 - 40 km westward in Acadian deformation. Transverse structures in the Humber Zone, notably at the southern margin of the Long Range and at Round Head on the Port au Port Peninsula, are interpreted as hangingwall ramps formed by reactivation of older normal faults within the platform succession.

Nº 29428

SOLUTION--REDEPOSITION AND THE ORTHOCLASE-MICROCLINE TRANSFORMATION. EVIDENCE FROM ADIRONDACK GRANULITES

WALDRON, Kim A., Dept. of Geology, Colgate University, Hamilton, NY 13346; PARSONS, Ian, Dept. Geology and Geophysics, University of Edinburgh, West Mains Rd., Edinburgh, EH9 3JW Scotland; BROWN, William B., CNRS-CRPG, F-54501, Vandoeuvre-lès-Nancy cedex, France.

Feldspar microtextures in Adirondack granulites suggest that the transformation of orthoclase to microcline has been accomplished by solution--redeposition.

The orthoclase (Or)-rich part of an optically mesoperthitic alkali feldspar was found to be cryptoperthitic when examined by transmission electron microscopy. A two-stage thermal history is proposed to explain the coarse and fine textures, with the cryptoperthite forming by coherent exsolution below 350-400 °C. Of particular interest are areas within the Or-rich cryptoperthite where the predominant twinned microtexture is cut by "seams" of microcline parallel to $\bar{b}$ and the cryptoperthite lamellae. The seams contain polygonal microcline subgrains and micropores (0.1-1.5 μm in diameter). Micropores have been linked with fluid-assisted subgrain formation and turbidity in feldspars. Subgrains, micropores and the twinned/microcline interfaces within the seams often have simple crystallographic indices characteristic of the Adulana habit. The Adulana habit is characteristic of feldspar that has grown in low temperature veins or in sediments and appears to develop during *in situ* solution--redeposition of alkali feldspar. The crystal habit of the microcline subgrains, the presence of micropores within the seams and the textural relationship between the seams and cryptoperthite lamellae suggest that low temperature fluid infiltration resulted in solution--redeposition of the alkali feldspar on a remarkably fine scale. Subsolidus recrystallization of feldspars in this fashion may have important geochemical implications, particularly for ^{18}O , ^{16}O exchange.

Nº 2874

LITHOSTRATIGRAPHY AND INTERNAL STRUCTURE OF THE OTTAUQUECHEE FORMATION, SOUTHERN VERMONT

WALSH, Gregory J. and RATCLIFFE, Nicholas M., U.S. Geological Survey, National Center, MS 928, Reston, VA 22092

Mapping in south-central Vermont demonstrates that the Ottauquechee Formation terminates as a mappable unit in the vicinity of Andover, probably due to fault truncations, and is not continuous southward to the Massachusetts border as shown on the Centennial Geologic Map of Vermont (Doll et al., 1961).

At the type locality in Bridgewater (E.L. Perry, 1927, 15th Rept. Vt. State Geol., p. 161) the Cambrian Ottauquechee Formation is 2.6 km thick and consists of black phyllite and dark-gray quartzite with lesser gray biotite-porphyroblastic phyllite, greenstone, and tan quartzose schist. In Plymouth the formation is 1.1 km thick and, in addition to the rock types at the type section, the Ottauquechee contains gray biotite-porphyroblastic plagioclase-quartz paragneiss, green biotite-porphyroblastic chlorite-quartz schist, serpentinite, and thin (<0.5 m) discontinuous pods of gray calcareous quartzite, black dolomitic marble, and gray carbonate-chlorite-quartz schist in a matrix of black phyllite and silvery quartz-mica schist. Near Ludlow the formation is 0.4 km thick and contains black phyllite and dark-gray quartzite, and in Andover it narrows to a single 3-m-thick dark-gray quartzite.

The belt is characterized by a north-striking east-dipping penetrative schistosity parallel to the contacts of the formation. Internal lithostratigraphic units, however, traverse the formation from northeast to southwest suggesting that the internal lithostratigraphy is oblique to the structural trend. The internal units are complexly isoclinally folded, and appear to truncate along internal faults and along the western contact with the Pinney Hollow Formation and the eastern contact with the Stowe Formation. Lithostratigraphic units in the adjacent formations also truncate along the Ottauquechee contact. This evidence suggests that the Ottauquechee Formation terminates by truncation between faults as the belt is traced southward from the type locality.

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The Symposium — continued

High-Resolution Flowmeter Logging — A Unique Combination of Borehole Geophysics and Hydraulics; Part II: Borehole Applications

Frederick L. Paillet; U.S. Geological Survey, Denver, CO; Crowder, Robert; COLOG Inc., Golden, CO; Hess, Alfred E.; U.S. Geological Survey, Denver, CO

Monitoring Well Completion Evaluation with Borehole Geophysical Methods

Robert Crowder, COLOG Inc., Golden, CO

Fracture Identification Using Full Waveform Acoustic Logs

C.H. Cheng, Earth Resources Lab, Cambridge, MA

Use of Borehole Electromagnetic Induction and Natural Gamma Logs To Delineate a Contaminant Plume in Ground Water

Thomas J. Mack, U.S. Geological Survey, Bow, NH

Analysis of Wellbore Image Data Applied to Environmental and Geotechnical Case Studies

C.A. Barton, Stanford University, Stanford, CA; Wright, J., Geophysics Branch, U.S. Bureau of Reclamation, Denver, CO

Assessment of Low-Level Radioactive Waste Using Borehole Spectra I Gamma-Ray Logging: A Case Study from Port Hope, Ontario

Dirk Kassenaar; Leask, David; Gartner Lee Inc., Niagara Falls, NY; Zelmer, Bob, AECL Research, Ontario, Canada

Downhole Shearwave Studies Enhanced by Gamma Log Lithologic Interpretations

D.L. Eggert, Indiana Geologic Survey, Bloomington, IN; Samuelson, A.C., Eckhoff W.R.; Ball State University, Muncie, IN

Use of a Perforating Gun as a Downhole Seismic Source at the DOE Hanford Site

Susan Narbutovskih, Westinghouse Hanford Company, Richland, WA; Michelsen, Finn, OYO Geospace, Houston, TX

Tuesday, March 29 **8:00 a.m. - 12:00 noon**

Poster Session III Site Characterization

High-Resolution Geophysical Survey of a RCRA Site

Gilein J. Steensma; Martin, Antony J.; Pendergraft, Darin M.; Johnson, Susan K.; Costa; Patti Kaye; IT Corporation, Irvine, CA

STOLSTM Magnetic Surveys at the Sandia National Laboratory and Offutt AFB

Jack Foley; Siegel, Robert; Geo-Centers, Inc., Newton Centre, MA

Seismic Measurements of Ground Displacements at the Superconducting-Supercollider Site

Dale Morgan; Lesmes, David; Massachusetts Institute of Technology, Cambridge, MA

Efficient, Cost Effective Waste Site Characterization Utilizing Complementary Non-Intrusive Geophysical Techniques: A Case Study of 2D and 3D Ground-Penetrating Radar and Magnetometer Surveys

W.R. Sims; Rucker, G.G.; Plunkett, R.A.; Westinghouse Savannah River Company, Aiken, SC

High-Resolution Marine Seismic Reflection Data Acquisition Using an Engineering Seismograph

Jeffrey S. Waldner, NJ Geological Survey, Trenton, NJ; Sheridan, Robert E., Rutgers University/Dept. of Geological Sciences, New Brunswick, NJ; Hall, David W., NJ Geological Survey, Trenton, NJ; Ashley, Gail M., Rutgers University/Dept. of Geological Sciences, New Brunswick, NJ;

Ground Penetrating Radar Survey of a Waste Disposal Area at the Site of a Former Lumber Mill

J. R. Pelton, Boise State University, Boise, ID

A United Kingdom Environmental Geophysics Test and Training Site

Ian Hill, Geology Department, Leicester University, U.K.; Peter Fenning, Earth Science Systems Ltd., Harpenden, U.K.

The Integration of Imaging and Parameter Estimation in Shallow Geophysics

A.J. Witten; Norton, S.; Oak Ridge National Laboratory, Oak Ridge, TN; Devaney, A.J.; Schatzberg, Alon; Northeastern University, Boston, MA; Ursic, J., U.S. EPA Region 5, Chicago, IL; Dickson, W., Dynamic Graphics, Inc., Bethesda, MD

Tuesday, March 29 **1:00 p.m. - 5:30 p.m.**

Poster Session IV Hydrogeophysics

Finding Potential Brine Discharge Sites along the Canadian River in Eastern New Mexico Using Electromagnetic Induction Methods

Jeffery G. Paine; Avakian, Arlen J.; Gustavson, Thomas C.; University of Texas at Austin, Austin, TX

Utility of Ground Penetrating Radar in an Integrated Remote Sensing Program To Map Peat Depths in High Latitude Wetlands

Ramona E. Pelletier, NASA-John C. Stennis Space Center, Stennis Space Center, MS

Application of Through-Ice GPR in a Wetland Investigation in Southwestern Michigan

William A. Sauck, Western Michigan University, Kalamazoo, MI

Identification of Hydraulically Conductive Fractures from the Analysis of Localized Stress Perturbations and Thermal Anomalies

C.A. Barton; Zoback, M. D.; Moos, D.; Stanford University, Stanford, CA

HIGH-RESOLUTION MARINE SEISMIC REFLECTION DATA ACQUISITION USING AN ENGINEERING SEISMOGRAPH

WALDNER, Jeffrey S., Drexel University, Dept Civil and Architectural Engineering, Philadelphia PA - NJ Geological Survey, CN427, Trenton, NJ 08625 (609) 984-6587; SHERIDAN, Robert E., Rutgers University, Dept. of Geological Sciences, New Brunswick, New Jersey, 08903 (908) 932-2044; HALL, David W., NJ Geological Survey; ASHLEY, Gail M., Rutgers University.

A digital single-channel seismic reflection system was developed to acquire continuous profiling data by interfacing a conventional analog system with a land-based digital signal enhancement engineering seismograph. Digital profiles are enhanced by trace static correction, deconvolution, automatic gain scaling, weighted horizontal stacking and digital filtering. Problems common to analog data such as wave motion effects of surface sources, water bottom reverberation, multiple reflections, and bubble pulse width can be addressed by the processing. The fast firing-rate for analog records is maintained while a trigger-divider sends a slower trigger rate to the digital seismograph. An auto-save feature with an automatic roll-along switch groups adjacent traces to files, eliminating system limitations of the mass storage device.

The digital data were collected to map sand ridges of the inner continental shelf off New Jersey for beach sand replenishment surveys. The seismic tracklines are correlated to vibracores and known geologic stratigraphy. The digital data exhibit reflections from layers less than 1 meter thick. Synthetic seismograms constructed from the vibracore information show these internal reflectors are caused by shelly gravel/medium sand interfaces. Global positioning system (GPS) was used to plot real-time position as well as obtain a navigational accuracy within 10 meters.

The combination of the analog system with the land-based seismograph offers a less expensive technique for digital acquisition and processing. This provides improved results over older analog data.

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