

# 90040

**16th Cruise of the R/V Akademik Boris Petrov (Leg 1)**  
(October 5 - November 15, 1990)

**Soviet-U.S. Collaborative Geological and Geophysical  
Survey of the Mid-Atlantic Ridge between 30°N and 34°N**

**Cruise Report**

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and nomenclature. Use of trade names is for the purposes of identification only and does not constitute endorsement by the U.S. Geological Survey.

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## SOVIET - U.S. COLLABORATIVE STUDIES OF THE MID-ATLANTIC RIDGE 30°N TO 34°N, 1989 AND 1990

The 16th cruise of the Soviet vessel R/V Akademik Boris Petrov was a U.S.-Soviet cooperative marine field program on the Mid Atlantic Ridge. This report describes Leg 1 of the 16th Cruise of the R/V Petrov in which dredging operations and multibeam-bathymetric, gravity, and magnetic surveying were conducted on the Mid-Atlantic Ridge between 30°N and 34°N (Figure 1). This investigation is part of the "Mid-Atlantic Ridge Crest Processes Project", a joint Soviet-U.S. project under the Soviet-U.S. Bilateral Ocean Studies Agreement (Ostenso, 1990). Initiated in 1988 as part of the renewal of the Soviet-U.S. World Oceans Agreement, the initial studies of this cooperative project were undertaken in February 1989 during Cruise 12 (Leg 1) of the R/V Akademik Boris Petrov of the Vernadsky Institute of Geochemistry (USSR Academy of Sciences, Moscow). Results from this initial study were used to develop the extensive geophysical surveying and geological sampling program undertaken on the 16th Cruise of the R/V Petrov. Both cruises involved scientists from the Vernadsky Institute of Geochemistry, U.S. Geological Survey, University of Houston, Northwestern University, and Woods Hole Oceanographic Institution.

### REGIONAL GEOTECTONIC FRAMEWORK

The region of study is along the axis of the Mid-Atlantic Ridge from 30°N to 34°N, part of the world-wide midocean ridge system. This is part of the ocean floor where new oceanic crust is generated at a spreading center. New igneous material is emplaced at and below the seafloor as two lithospheric plates separate at their plate boundary. For this region, the Mid-Atlantic Ridge separates the African and North American plates, which are separating at a rate of 24 mm/yr to 28 mm/yr (Fox and Gallo, 1986; Klitgord and Schouten, 1986; Macdonald, 1986). This part of the midocean ridge system is classified as a slow spreading center. The survey area lies just to the south of the Azores Triple Junction, where the North American, African, and European plate boundaries intersect. The Azores "hot spot" and its associated geochemical anomalies lies astride this triple junction. The plate boundary between 30°N and 34°N consists of numerous spreading-center segments offset by transform zones with various offset lengths. The Atlantis and Hayes Fracture Zones are the two large-offset transform zones that bound this section of the Mid-Atlantic Ridge, and they have right-lateral offsets of the ridge axis (left-lateral transform fault motion) of 60 km and 80/120 km respectively. The Hayes Fracture Zone is presently a double transform zone where the ridge axis to the north is offset first 80 km to the east and then another 40 km to the east. There are at least four shorter ridge-axis right-lateral offsets along this ridge section, including the Petrov Fracture Zone at 31°N with a 20-km offset (Figure 2), a 10-km offset near 31°45'N, a 15 to 20-km offset near 32°40'N, and a 20 to 25-km offset near 33°N. In addition, there are numerous "zero-offset" transform zones (Schouten and Klitgord, 1982) associated with minor ridge crest offsets and discontinuities. The ocean crust surveyed between the Atlantis and Hayes Fracture Zones during this program includes sea-floor spreading magnetic lineations from the Central Anomaly out to Anomaly 2', zero to 3.5 m.y. old crust. The oldest crust possibly sampled during the dredging program was 9 m.y. old crust on the southeast wall of the large-offset Hayes Fracture Zone. Up to 5 m.y. old crust may have been sampled from the walls of the Atlantis Fracture Zone. This older crust was exposed to dredge sampling because of the large transform offsets. These sites in the two large-offset transforms were selected using pre-existing swath-mapping bathymetric maps and they were not surveyed during this cruise.

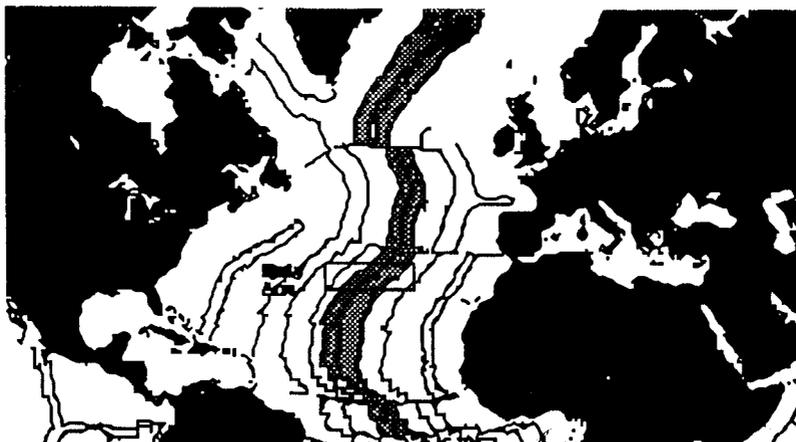


Figure 1. Generalized map of the Mid-Atlantic Ridge with approximate location of R/V Petrov survey area.

## CRUISE 12 (Leg 1) R/V AKADEMIK BORIS PETROV

In February 1989, a Soviet-U.S. joint marine geological and geophysical study was initiated along the Mid-Atlantic Ridge near 31°N on the 12th Cruise of the R/V Akademik Boris Petrov. U.S. scientists from the U.S. Geological Survey, University of Houston, and Woods Hole Oceanographic Institution participated in this program with Soviet scientists from the Vernadsky Institute of Geochemistry, Institute of Geology, Schmidt Institute of Physics of the Earth, and Institute of Terrestrial Magnetism, all institutes of the USSR Academy of Sciences in Moscow.

This marine study involved a limited multibeam-bathymetric, gravity, magnetic, and seismic-reflection survey and dredge-sampling program of a short-offset transform fault named the Petrov Fracture Zone near 31°N. Thirteen dredge stations were completed at the Oceanographer, Hayes, and Petrov Fracture Zones. Eleven of these dredge stations and a detailed geophysical survey were located in a localized region within the Petrov Fracture Zone and the adjacent ridge segments (Figure 2) (Dmitriev, Klitgord, and others, 1989; Casey, Dmitriev, and others, 1989). Petrologic studies of these samples show a distinctive geochemical anomaly associated with this transform fault. The geochemical trends observed from ridge segments to the transform domains indicate depletions in incompatible elements and certain distinctive elemental ratios (e.g., Ce/Yb) thought not to undergo significant changes during closed system fractional crystallization. These trends are opposite to the trends that have been previously proposed to result from the "transform-fault effect" (Bender and others, 1984). Samples from a single dredge site in the Hayes Fracture Zone showed a geochemical signature relative to the adjacent ridge segments similar to the trend found at the Petrov Fracture Zone. These geochemical signatures suggested that further studies in the area between 30°N and 34°N may be key in understanding the nature of short-wavelength geochemical variations along zero-age crust of slow-spreading ridge segments and the association of geochemical changes with long- and short-offset transform faults as well as other small-scale axial discontinuities.

## CRUISE 16 (Leg 1) R/V AKADEMIK BORIS PETROV

The 16th cruise of the R/V Akademik Boris Petrov was conducted in the north and central Atlantic Ocean (Figure 1) as part of the Soviet-U.S. cooperative research project "Mid-Atlantic Ridge Crest Processes" within the framework of the Soviet-U.S. bilateral Ocean Studies Agreement. The primary survey sites were located along the Mid-Atlantic Ridge between 30°N and 34°N, in the area of the Atlantis, Petrov, and Hayes Fracture Zones. Cruise 16 was split into two legs: the first leg focused on the Mid-Atlantic Ridge between 30°N and 34°N; the second leg focused on the Mid-Atlantic Ridge near 15°N. This cruise report details the studies and initial results from the first leg of the 16th cruise. Dr. Sergei Silantiev of the Vernadsky Institute of Geochemistry, USSR Academy of Sciences, Moscow, was the Soviet chief scientist on both legs of cruise 16, which included scientists from the Vernadsky Institute of Geochemistry, Institute of Geology, Schmidt Institute of Physics of the Earth, and Institute of Terrestrial Magnetism, all institutes of the USSR Academy of Sciences in Moscow. The U.S. scientists participating in the first leg of this Petrov cruise were K.D. Klitgord (U.S. Geological Survey), J.F. Casey (University of Houston), S.M. Agar (Northwestern University), and W.B. Bryan (Woods Hole Oceanographic Institution). A complete list of the scientific personnel on leg 1 is given in Appendix 1. The first leg of the cruise departed from Copenhagen, Denmark on October 5th, 1990 and ended in Bridgetown, Barbados on November 15th, 1990. Log of the ship's schedule during this cruise is given in Appendix 2.

The operational plan for the studies on this cruise was developed as a cooperative effort between U.S. and Soviet scientists. Having established jointly the basic objectives of the study, the U.S. scientists were given the responsibility for developing the detailed survey and dredge sampling plans. Dredge operations and basic geophysical systems operations were the responsibility of the Soviet personnel. The U.S. scientists were responsible for the sample curation, including initial rock descriptions, cataloging, labelling, and distribution. Final shipboard rock descriptions and sample splitting were based on mutual agreement between U.S. and Soviet scientists. Representative rock samples from each dredge locale were selected for cutting slabs and making thin sections onboard. Many rock samples were split, with the U.S. and Soviet groups each taking half. This split was agreed upon to enable us to divide the shore-based analytical work and to provide samples upon which the same analyses could be carried out for calibration of systems and techniques. A summary of the dredge stations and brief description of samples recovered at each station are given in Appendix 6.

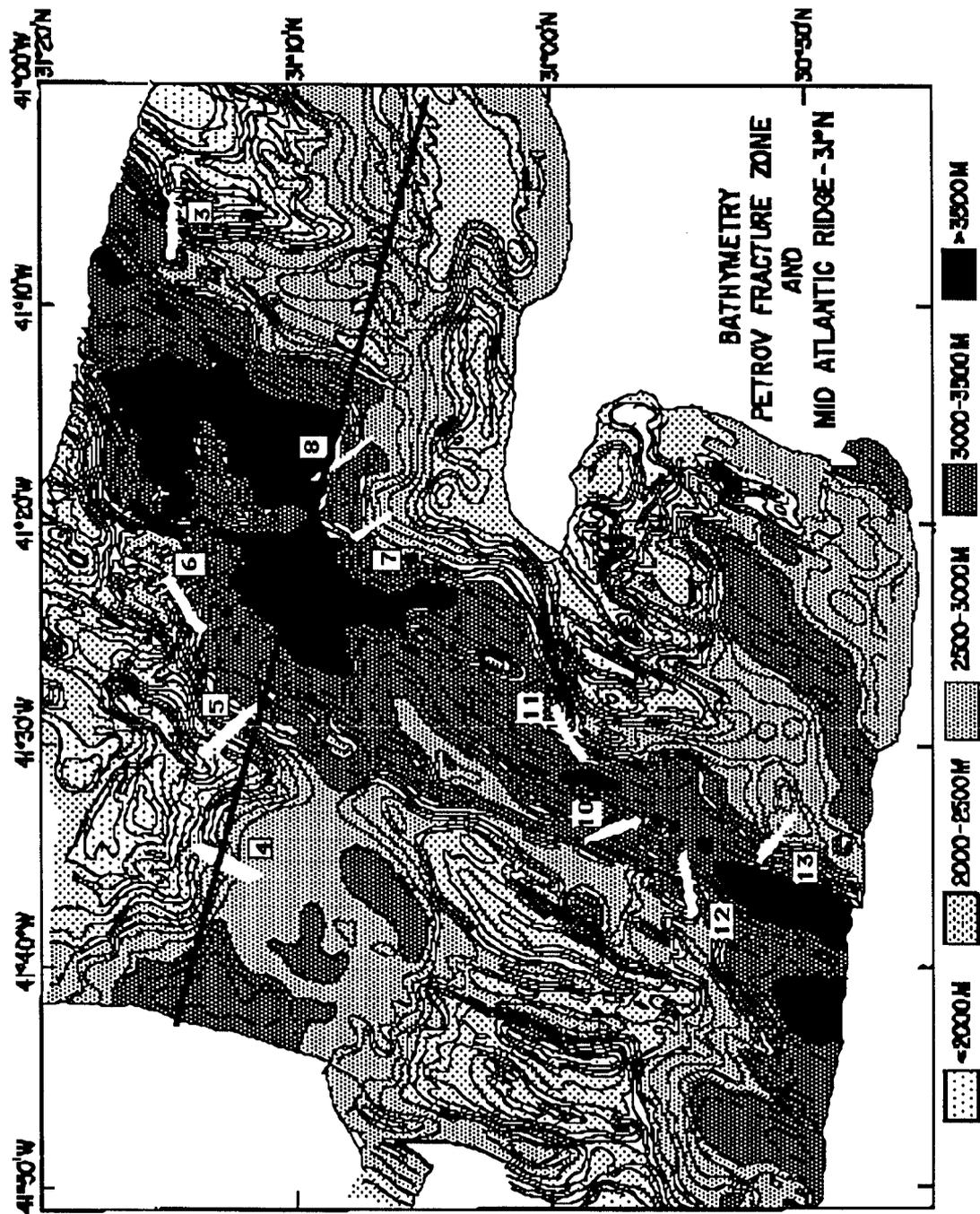


Figure 2. Bathymetric map of the Petrov Transform Zone from multibeam data collected during the 1989 Petrov survey. Dredge localities also shown.

## SCIENTIFIC OBJECTIVES

Overall objective of the 16th cruise leg 1 of the R/V Petrov was to undertake an integrated geological sampling and geophysical surveying program on the Mid-Atlantic Ridge between the Atlantis Fracture Zone and the Hayes Fracture Zone, from 30°N to 34°N (Figure 3). This survey area includes the Petrov Fracture Zone region of the Mid-Atlantic Ridge near 31°N (Figure 2), which was surveyed and sampled during the 12th cruise of the R/V Petrov in February 1989 as part of this same cooperative research project. This present study was designed to complete and expand this earlier study. The addition of Global Positioning System (GPS) satellite navigation on this present cruise enabled us to calibrate the 1989 studies via selected survey tielines across the old survey. This calibration permits us to merge these two data sets into one comprehensive geophysical survey from 30.5°N to 32.5°N. The geophysical surveying was conducted using multibeam swath-mapping bathymetric, magnetic, and gravimetric systems and over 6000 km of profiling were completed. Bottom sampling was undertaken with large, Soviet barrel dredges, and 46 dredge stations were completed on this leg.

The sampling and survey program was designed to address specific scientific objectives related to understanding the geological, geochemical, and geodynamic processes that help to control the generation and subsequent deformation of oceanic lithosphere. These scientific objectives are summarized as follows:

1. Establishing the morpho-tectonic framework of the axial Mid-Atlantic Ridge by:
  - a. identifying and mapping the large-offset, small-offset, and "zero-offset" transform/fracture zones.
  - b. identifying and mapping the axial bathymetric high, rift-valley graben, and flanking fault blocks including the segmentation characteristics of the ridge.
  - c. identifying and mapping magnetic lineations that provide age-isochron information and other magnetic signatures that reflect magmatic processes at the ridge.
  - d. identifying and mapping the gravity signatures of the ridge segments and fracture zones.
  - e. model studies of these magnetic and gravimetric signatures.
2. Establishing the magmatic contribution to oceanic crustal generation by:
  - a. determination of the geochemical variations along the ridge axis in young oceanic crust.
  - b. examination of the relationships between these variations and ridge segmentation
  - c. examination of small-scale variations at large-offset, small-offset, and zero-offset transform zones.
3. Investigating the deformation of oceanic crust within transform/fracture zones by:
  - a. establishing the metamorphic character of mafic and ultramafic rocks, including microfabric, fluid-inclusion, and geochemical evidence.
  - b. establishing the deformation history of mafic and ultramafic rocks, including microfabric, fluid-inclusion, isotopic, and geochemical evidence.

## GEOPHYSICAL INVESTIGATIONS

Geophysical studies were undertaken using bathymetric swath-mapping, magnetic, and gravimetric systems, and we acquired nearly 6000 km of profile data. On this cruise, all of the systems were provided by the Soviets on the Petrov, and there were specialist teams for each of these systems. Navigation was upgraded this year to include a Magnavox GPS MX5400 satellite navigation system. A summary of the geophysical systems is given in Appendices 3 and 4. Data logging and some initial data processing were carried out on three IBM-compatible PC-XT's and an IBM-compatible PC-AT in conjunction with the Soviet mainframe EC-1011C computer (similar to a PDP-11 computer). The U.S. research team brought onboard two Macintosh-SE personal computers with a 40Mb removable hard-disk system, a IBM-PC laptop computer, and an IMAGEWRITER-II printer to facilitate geophysical-data logging, record keeping, rock-sample logging, survey scheduling, report writing, and graphic output of cruise results.

The primary geophysical data acquired on this cruise was the swath-bathymetry information. Previous swath-mapping, bathymetric surveys in the region include a detailed survey in 1988 using the R/V Conrad from the Kane to Atlantis Fracture Zones (north to 30°40'N) by researchers from Woods Hole Oceanographic Institution (Schouten et al., 1991), our survey of the Petrov Fracture Zone area in 1989, and a survey of the Hayes Fracture Zone by the Naval Oceanographic Office (Smoot, 1989). The magnetic and gravity data collected on this cruise extends northward the grid of these data acquired with the Conrad in 1988 (Figure 3).

The geophysical surveys were designed to meet three objectives:

1. calibrate with GPS navigation the geophysical survey lines acquired during the 1989 survey of the Petrov Fracture Zone region by acquiring a series of tielines across the survey area.
2. complete survey of the Petrov Fracture Zone area by:
  - a. filling in the gap between the 1989 survey with the R/V Petrov and the 1988 swath-mapping survey of the Atlantis Fracture Zone with the R/V Conrad.
  - b. augmenting survey of the southern wall of the eastern Petrov Fracture Zone.
3. extend the geophysical survey of the Mid-Atlantic Ridge northward from the Petrov Fracture Zone (31°N) to the Hayes Fracture Zone (33.5°N).

The survey lines used to complete these three objectives are shown in Figure 3. The more systematic part of the survey was carried out with 70-km long track lines oriented along 102° east-southeast. This trend is approximately orthogonal to the ridge axis orientation. An average track spacing of 3 km was used to acquire over 50% complete bathymetric coverage with the swathmapping system. The tie lines were acquired from the Atlantis Fracture Zone survey area to the Hayes Fracture Zone in anticipation of future swath-mapping bathymetric surveys completing the bathymetric survey coverage of this entire section of the Mid-Atlantic Ridge. Combined with the 1989 Petrov and 1988 Conrad surveys, the dense bathymetric and geophysical surveys provide complete coverage of the ridge axis between 30°N and 32°20'N.

### Data Distribution

Navigation, swath-bathymetric, gravimetric, and magnetic data were stored digitally on magnetic tapes, floppy disks, and removable hard disks. The navigation and swath-bathymetry data are stored in the GF-3 format, and this format is detailed in Appendix 5. The navigation data have been subjected to only a preliminary editing, so a final navigation files is not yet available. U.S. scientists were provided with digital copies of all these data, and copies are stored at both the U.S. Geological Survey, Woods Hole and the Department of Geosciences, University of Houston.

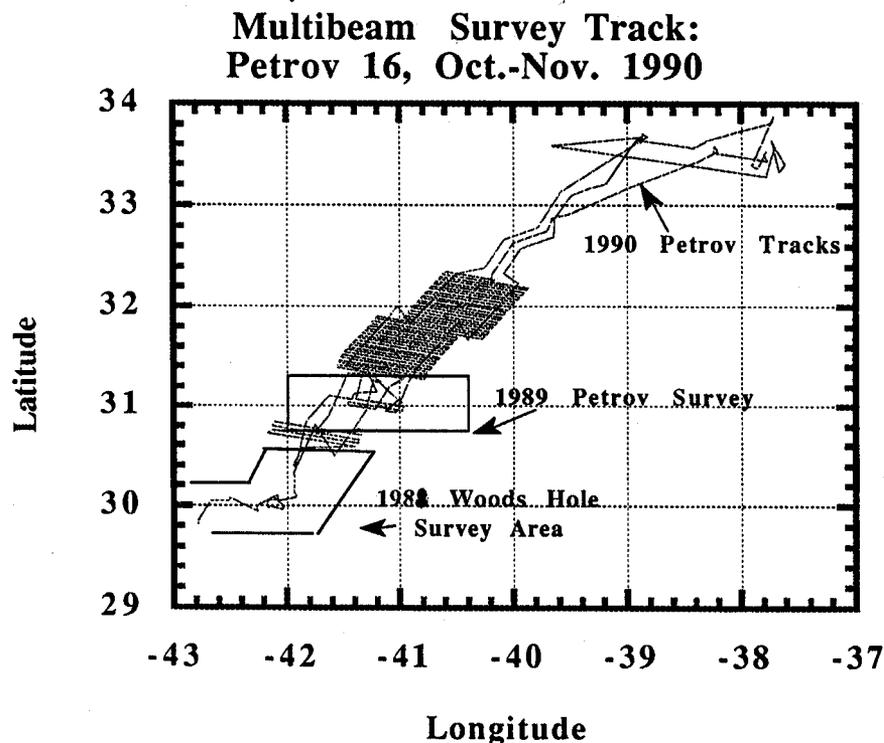


Figure 3. Generalized map showing ship tracks of the 1990 survey of the R/V Akademik Boris Petrov. Also shown are regions of the 1988 survey of the R/V Conrad and the 1989 survey of the R/V Petrov.

## GEOLOGICAL INVESTIGATIONS

A detailed rock-sample dredging program was coupled with the geophysical surveys (see Figure 4 for dredge localities). Along the central axial high of the ridge segments (zero-age crust), we conducted one dredge every 12 km of ridge length from the Atlantis to the Hayes Transform Zones, including sites at both ridge-transform intersections (RTI) of these two fracture zones. Extensive dredge sites were also focused on the walls of the Atlantis, Petrov and Hayes Fracture Zones. The localities of these dredge sites are shown on expanded maps in Figures 5a,b,c. A summary of the dredge sites and samples acquired at these sites is given in Appendix 6.

The purposes of the dredge sites were split between the two major objectives of looking at geochemical variations along the ridge axis and examining the deformation of crustal rocks within transform zones. J.F. Casey and W.B. Bryan were primarily responsible for the ridge axis sampling program. S.M. Agar and S. Silantiev were responsible for the fracture zone sampling program. Twenty eight (28) dredge sites were focused on the rift valley axial-high, zero-age crust investigation and eighteen (18) dredges were placed within transform-fault, fracture-zone locales. The combined sampling of the 1989 and 1990 Petrov cruises has resulted in 53 dredge stations; 43 out of 53 dredges recovered at least a small amount of basement material and several thousand kilograms of rock is now available for study. Poor recovery on several dredges along the northern ridge section between 32°20'N and the Hayes Transform Zone (33°30'N) has left data gaps in this area. Most of the dredges within the rift valley recovered fresh glass on near-zero age crust. All of the rocks recovered from these ridge axis sites were of basaltic origin, including aphyric as well as plagioclase and olivine phryic samples. All dredges from both cruises in the Petrov Fracture Zone have yielded only basaltic samples. In contrast, suites of basaltic, gabbroic, and ultramafic rocks were recovered by dredging within both the Hayes and Atlantis Transform Zones. Variable amounts of brittle and plastic deformation, including shearing, fracture and vein development, serpentinization, and low-grade metamorphism, characterize samples from this latter data set. A brief description of these samples is given in Appendix 6.

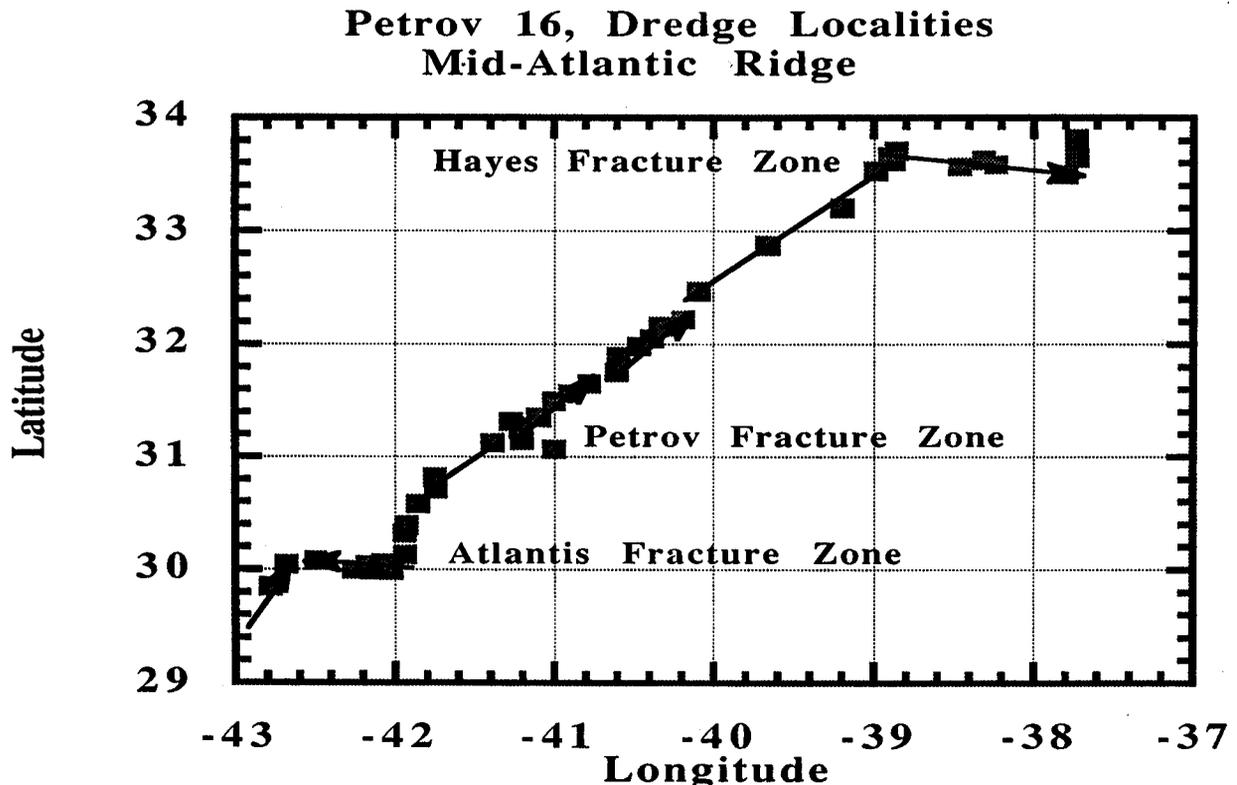


Figure 4. Dredge stations occupied during the 1990 survey of the Mid-Atlantic Ridge from 30°N to 34°N during Cruise 16 (Leg 1) of the R/V Akademik Boris Petrov.

## Sample Distribution

The rock collection acquired on this cruise is to be housed at the Vernadsky Institute of Geochemistry in Moscow and at the Department of Geosciences, University of Houston, Houston, with approximately 50% of the rock samples located at each place. A subset of this rock data set for the samples acquired within the fracture zones is also kept at the Department of Geological Sciences, Northwestern University. All of the sedimentary samples were sent to the University of Houston. The rock samples were generally divided into two roughly equal collections for the Soviet and U.S. scientists where there was abundant material available in individual dredges. In cases where there was a sparse amount of material in individual dredges, many of the samples were cut in half so that each side could have a representative sampling of each dredge haul. All of the samples are to be subjected to systematic chemical analyses in both Moscow and the U.S., including whole-rock major element, trace element, and isotopic analyses of basaltic and plutonic rocks and microprobe and ion-probe studies on glasses, minerals, and melt inclusions. Petrofabric and microstructural analyses will be carried out at Northwestern University on the plutonic and metamorphic rock samples. Thin sections were made of many of the samples on board the ship. These samples are indicated in Appendix 6. A complete set of these thin sections was sent back to Moscow, and a small subset of duplicate thin sections was taken to University of Houston, Northwestern University, and Woods Hole Oceanographic Institution. Additional thin sections are being made at these latter three institutions for more detailed analytic studies.

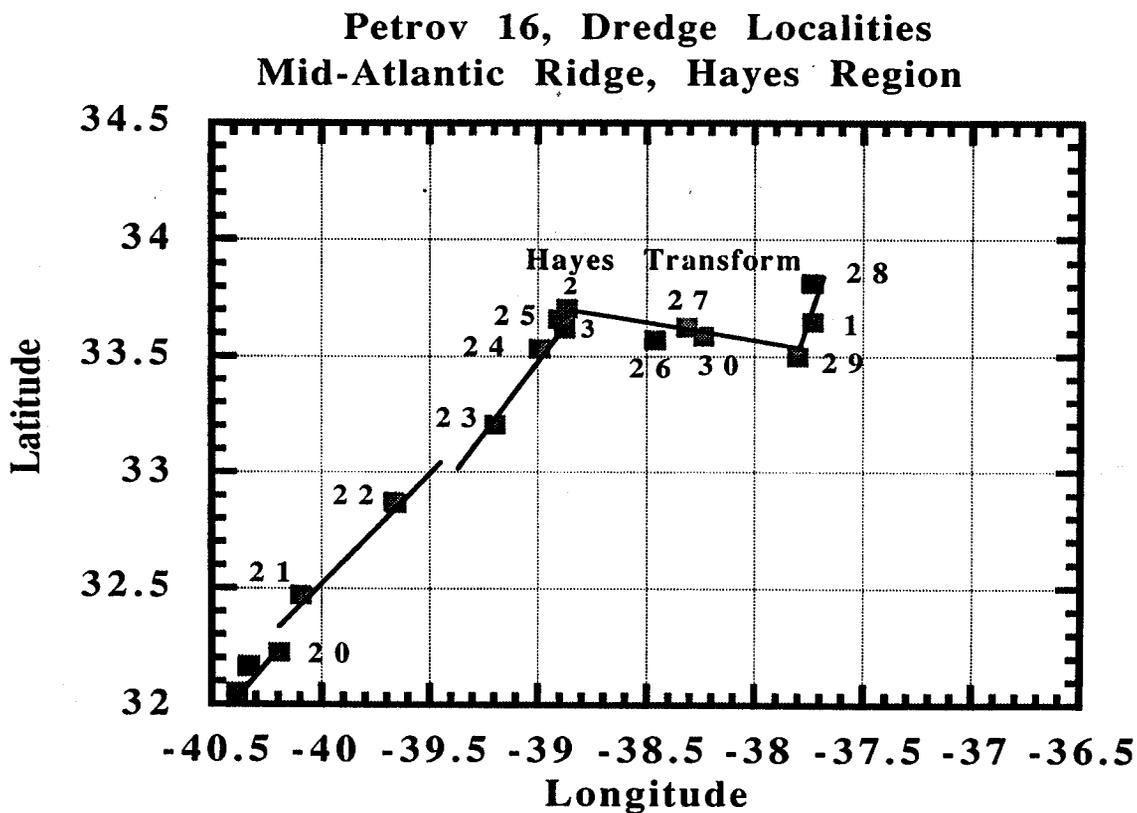
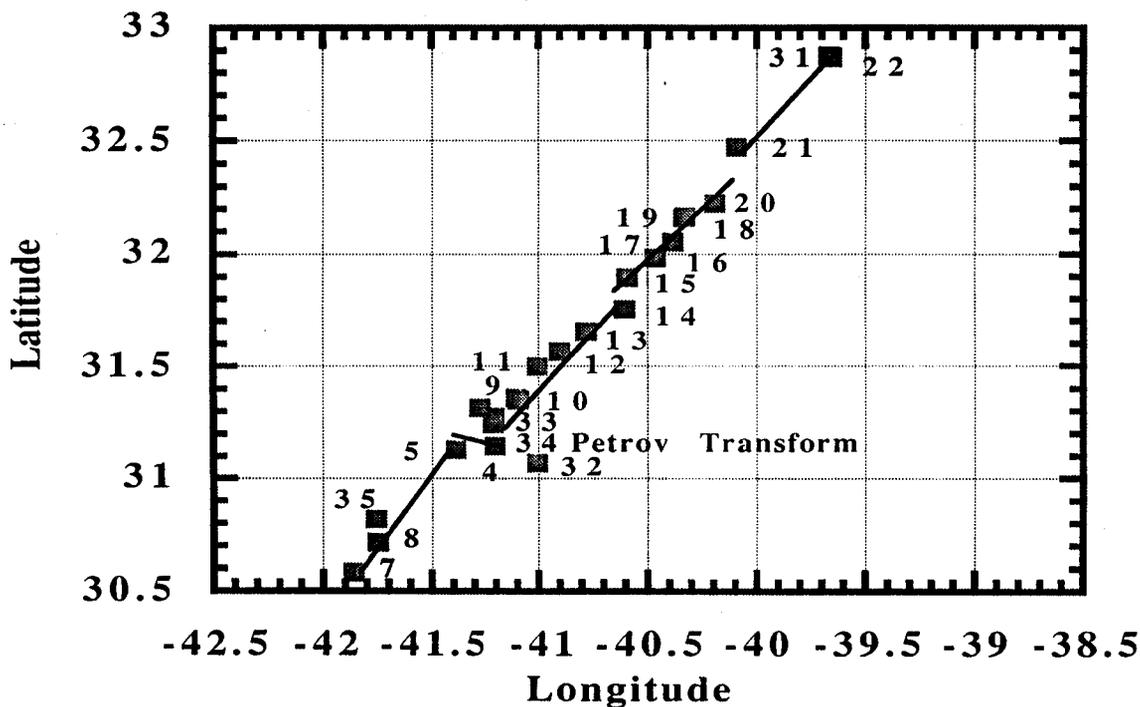


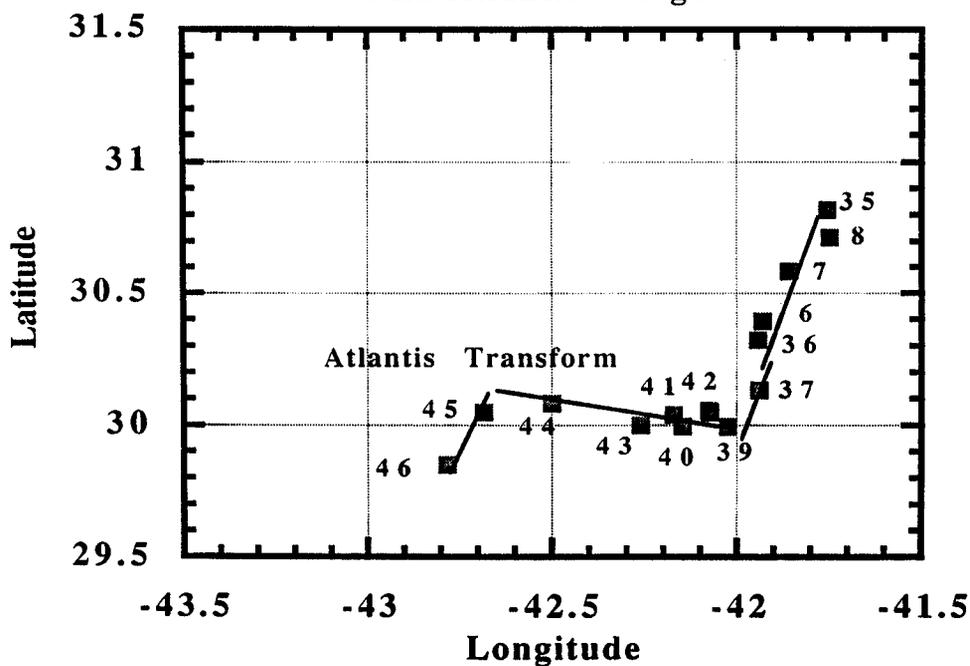
Figure 5a. Dredge locality map for the Hayes Fracture Zone region. For discussion of dredge sites numbered in diagram and description of samples from these dredge site refer to Appendix 6.

**Petrov 16, Dredge Localities**  
**Mid-Atlantic Ridge, Petrov Region**



**Figure 5b.** Dredge locality map for the Petrov Fracture Zone region. For discussion of dredge sites numbered in diagram and description of samples from these dredge site refer to Appendix 6.

**Petrov 16, Dredge Localities**  
**Mid-Atlantic Ridge**



**Figure 5c.** Dredge locality map for the Atlantis Fracture Zone region. For discussion of dredge sites numbered in diagram and description of samples from these dredge site refer to Appendix 6.

## POST-CRUISE DATA PROCESSING

Post-cruise analysis responsibilities and schedules have been established for all of the information acquired during this cruise. A primary goal is to obtain preliminary data results by Fall 1991 for joint evaluation and interpretation and then manuscript preparation.

### Geophysical Analyses

#### USSR:

1. Navigation Data: Initial editing and merging (Antropov).
2. Bathymetric Data: Analog compilation of multibeam data and preparation of initial bathymetric chart (Turko, Pavlenko).
3. Gravity Data: Base station ties at port sites, data leveling, and initial data analysis (Korenfeld).
4. Magnetic Data: Data digitizing from original analog records (Mayorshin and Ostroukhov).

#### US:

1. Navigation Data: Final navigation processing and merging with navigation data from Petrov 12 cruise (Klitgord).
2. Bathymetric Data: Digital processing of multibeam data and merging with bathymetric data from Petrov 12 Cruise. Bathymetric contour-map generation for Atlantis Fracture Zone to Hayes Fracture Zone. Bathymetric cross sections for dredge locations (Klitgord).
3. Gravity Data: Regional field removal, Eivos Corrections, and Free-Air anomaly calculations (Klitgord). Model studies and initial interpretation (Klitgord and Casey).
4. Magnetic Data: Regional field removal, model studies, and initial interpretation (Klitgord).
5. Digital Data Bases: Regional tectonic-features, bathymetric, geologic, and geochemical data sets (Klitgord, Casey, Bryan, and Agar).

### Petrologic and Geochemical Analyses

#### USSR (starting Jan. 1991):

1. General petrology: (Silantiev, Magakyan, Zlobin, Bazylev, Bogdanovskiy, and Gurenko).
2. Whole-rock analyses: (Silantiev, Magakyan, Zlobin, and Bazylev).
3. Mineral chemistry: Residual ultramafics and plutonic rocks. (Bazylev, Silantiev, Zlobin, and Magakyan).
4. Isotopic analyses: Sr, Nd (Bogdanovskiy and Silantiev).
5. Glass analyses: (Dmitriev and Magakyan).
6. Phenocryst-melt inclusion studies: Primary melt compositions (Magakyan, Gurenko, Zameryan).
7. Mineral analyses: Metamorphic rocks. preliminary metamorphic history (Silantiev).

US (starting December 1990)

1. General petrography: Quantitative nodal analysis (Bryan - Casey).
2. Whole-rock, major element, trace-element, and REE analyses:  
Basalts (ICP - Casey).
3. Mineral chemistry and whole-rock geochemistry:  
Plutonic rocks and residual peridotites (Casey).
4. Isotopic analyses: Sr, Nd, Pb, He (Kurz).
5. Glass analyses: (Microprobe - Casey).
6. Glass/phenocryst trace element studies:  
(Ion probe - Bryan).
7. Phenocryst analyses: (Microprobe - Bryan).
8. Experimental petrology: Phase equilibria (Bryan).
9. C-14 dating of coral: (Bryan).
10. 40Ar/39Ar dating: (Casey).

#### Structural and Microfabric studies

US:

1. Microfabric analyses: SEM studies and microphotographs (Agar).
2. Fault Deformation history: Microstructural and geomorphic studies (Agar and Klitgord).
3. Fracture-zone deformation: Plate kinematics and rock-deformation studies (Agar and Klitgord).

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## APPENDIX 1

### SCIENTIFIC PERSONNEL

- a. Dr. Sergei Silantiev - Soviet co-chief scientist; metamorphic petrologist  
Laboratory of Geochemistry of Magmatic and Metamorphic Rocks  
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- b. Dr. Kim D. Klitgord - U.S. co-chief scientist; geophysicist  
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- e. Dr. Wilfred Bryan - petrologist  
Woods Hole Oceanographic Institution, Woods Hole, MA 02543 USA
- f. Sergei Zlobin - petrologist - Deputy chief of expedition  
Vernadsky Institute of Geochemistry, Moscow, USSR
- g. Ruben Magakyan - petrologist - chief of dredge operations  
Vernadsky Institute of Geochemistry, Moscow, USSR
- h. Oleg Bogdanovskiy - petrologist - Scientific secretary of expedition  
Vernadsky Institute of Geochemistry, Moscow, USSR
- i. Dr. Vitaliy Korenfeld - gravity specialist in charge of gravity system  
Institute of Physics of the Earth, Moscow, USSR
- j. Alexander Sindyukov, gravity technician  
Institute of Physics of the Earth, Moscow, USSR
- k. Yuri Konoplev, gravity technician  
Institute of Physics of the Earth, Moscow, USSR
- l. Vladimir V. Mayorshin - magnetic specialist in charge of magnetometer system  
Institute of Terrestrial Magnetism - Troizk, Moscow, USSR
- m. Nikolai Ostroukhov, magnetics technician  
Institute of Terrestrial Magnetism - Troizk, Moscow, USSR
- n. Natalya Turko - multibeam bathymetry specialist in charge of multibeam bathymetric system  
Laboratory of marine geomorphology and seismo-acoustics  
Institute of Geology, Moscow, USSR
- o. Yecaterina Pavlenko, cartographic and aerophoto specialist; assistant of Turko  
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- p. Igor V. Antropov - computer software specialist; responsible for data logging and processing  
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- q. Mikhail Miromenko - computer hardware operations; geochemist  
Vernadsky Institute of Geochemistry, Moscow, USSR
- r. Boris Bazylev - ultramafic petrologist; dredge operations team  
Vernadsky Institute of Geochemistry, Moscow, USSR
- s. Andrei Gurenko - petrologist/student; Agar's sample cataloging team/ dredge operation team  
Vernadsky Institute of Geochemistry, Moscow, USSR
- t. Andrei Koshkin - petrologist/student; Casey's sample cataloging team/ dredge operation team  
Institute of Geology, Moscow, USSR
- u. Lyudmila Polosina - thin-section lab operations  
Vernadsky Institute of Geochemistry, Moscow, USSR
- v. Olga Tsameryan - petrologist; multibeam bathymetry watch  
Vernadsky Institute of Geochemistry, Moscow, USSR

### SHIP'S PERSONNEL

Ship's captain: Igor Vtorov  
Captain Assistant: Georgiy Vdovenko  
Scientific mate: Yuri Shalimov  
Electronics specialist: Alexander Latko

APPENDIX 2

Ship's Log For Cruise 16 (Leg 1) of R/V Akademik Boris Petrov

N		A		B		C		D	
Label	Time (Local)	Event	Location	Sample Description					
1	10/5/90	2200h	Depart Copenhagen	start of A. Boris Petrov Cruise 16					
2	10/6/90	0000h-2400h	transit	around Denmark					
3	10/7/90	0000h-2400h	transit	thru North Sea					
4	10/8/90	0000h-2400h	transit	thru North Sea					
5	10/9/90	0000h-2400h	transit	thru English Channel					
6	10/10/90	0000h-2400h	transit	thru English Channel					
7	10/11/90	0000h-2400h	transit	northeast Atlantic					
8	10/12/90	0000h-2400h	transit	northeast Atlantic					
9	10/13/90	0000h-2400h	transit	northeast Atlantic					
10	10/14/90	0000h-2400h	transit	northeast Atlantic					
11	10/15/90	0000h-2400h	transit	northeast Atlantic south of Azores					
12	10/16/90	0000h-0230h	transit	northeast Atlantic south of Azores					
13	10/16/90	0230h-0800h	site survey for D-1	east end Hayes FZ					
14		0800h-1200h	winch repairs						
15		1200h-1700h	Dredge #1	east end Hayes FZ on tilted block					49 samples gabbros/dolerites w/basalt; layer 2/3 bdrly
16		1700h-2400h	MGM survey 160nm	geophys. transect south of Hayes FZ					brecciated w/greenschist metamorphic grade
17	10/17/90	0000h-1000h	cont. MGM survey						
18		1000h-1600h	Dredge #2	west end Hayes FZ on steep scarp					no samples - dredge lost
19		1600h-1700h	medical problem	must stay near Azores for 8hrs					
20		1700h-2300h	Dredge #3	same site as Dredge #2					mud only
21	10/18/90	0000h-2100h	MGM survey 220nm	title line from Hayes to Petrov FZ					
22		2100h-2400h	Dredge #4	Ridge axis, east Petrov FZ RTI					more than 200 pieces of basalt and basaltic glass
23	10/19/90	0000h-0300h	cont. Dredge #4						plagiophyric, olivine phyritic & aphanitic
24		0300h-0400h	transit 10 nm						
25		0400h-0800h	Dredge #5	Ridge axis, central Petrov FZ					12 small basalt chips and glass (from flows?)
26		0800h-1200h	transit 45 nm						fresh, aphanitic, glassy basalt
27		1200h-1600h	Dredge #6	Ridge axis - north of Atlantis FZ					medium size collection of fresh basalts w/ glass
28		1600h-1700h	transit 10 nm	dredge 6 to dredge 7					
29		1700h-2100h	Dredge #7	Ridge axis north of Atlantis FZ					9 samples Plagiophyric basalts w/glass
30		2100h-2400h	MGM survey 220nm	Gap between Petrov/Atlantis FZs					large pillow tube fragment
31	10/20/90	0000h-2100h	cont. MGM Survey						
32		2100h-2400h	Dredge #8	Ridge axis - gap survey area					no samples - dredge and wire lost
33	10/21/90	0000h-0100h	Dredge #8						
34		0100h-0700h	winch/wire/dredge	repairs of lost wire/dredge					
35		0700h-1900h	MGM Survey 130nm	Petrov FZ - tie lines and east end					
36		1900h-2400h	MGM Survey 210nm	Survey segment 1 north of Petrov					
37	10/22/90	0000h-1700h	cont. MGM survey						
38		1700h-2000h	mechanical work	making new dredge wire					

	A	B	C	D
39	2000h-2400h	Dredge # 9	Ridge axis central volcanic high	mud w/basalt chips and glass
40	0000h-0300h	Dredge # 10	same locale as Dredge #9	11 samples basalt + glass & chips; plagiophyric
41	0300h-2100h	MGM Survey 180nm	Survey segment 2 north of Petrov	12 samples ophanitic basalts + glass & chips
42	2100h-2400h	Dredge # 11	Ridge axis central volcanic high	with some plagioclase phenocrysts
43	0000h-1800h	MGM Survey 180nm	Survey segment 3 north of Petrov	14 samples basalt + glass, chips, mud
44	1800h-2100h	Dredge # 12	Ridge axis central volcanic high	with some plagioclase and olivine phenocrysts
45	2100h-2400h	MGM Survey 180nm	Survey segment 4 north of Petrov	
46	0000h-1500h	cont. MGM survey		no samples
47	1500h-1800h	Dredge # 13	ridge axis central volcanic high	
48	1800h-2400h	MGM Survey 180nm	Survey segment 5 north of Petrov	
49	0000h-1300h	cont. MGM survey		basalt chips with glass in mud
50	1300h-1700h	Dredge # 14	Ridge axis central volcanic high	
51	1700h-2400h	MGM Survey 220nm	Survey segment 6 north of Petrov	
52	0000h-1300h	cont. MGM survey		
53	1300h-1700h	Dredge # 15	Ridge axis central volcanic high	5 samples basalt + chips & mud; without glass
54	1700h-2400h	MGM Survey 180nm	Survey segment 7 north of Petrov	with plagioclase and olivine phenocrysts
55	0000h-1000h	cont. MGM survey		
56	1000h-1300h	Dredge # 16	Ridge axis central volcanic high	7 samples basalt + chips & w/glass
57	1300h-2400h	MGM survey 180nm	Survey segment 8 north of Petrov	with plagioclase phenocrysts
58	0000h-0500h	cont. MGM survey		
59	0500h-0800h	Dredge # 17	Ridge axis central volcanic high	3 samples aphanitic basalts + chips + mud & w/glass
60	0800h-2400h	MGM survey 180nm	Survey segment 9 north of Petrov	
61	0000h-0300h	Dredge # 18	Ridge axis central volcanic high	no samples
62	0300h-0500h	winch repairs	D-18 down 1000m wire only	winch broken and dredge operation aborted
63	0500h-0900h	Dredge # 19	same location as D-18	6 small basalt chips & glass in mud
64	0900h-2400h	MGM survey 140nm	Survey segment 10 north of Petrov	
65	0000h-0800h	engine repairs	main drive failed. Dead in water	
66	0800h-1100h	Dredge # 20	ridge axis central volcanic high	mud only
67	1100h-1300h	MGM transit 15nm	Axis tie line to Hayes FZ	dredge lost
68	1300h-1800h	Dredge # 21	ridge axis central volcanic high	
69	1800h-2100h	MGM transit 30nm	Axis tie line to Hayes FZ	mud only
70	2100h-2400h	Dredge # 22	ridge axis central volcanic high	
71	0000h-0300h	MGM transit 30nm	Axis tie line to Hayes FZ	
72	0300h-0600h	Dredge # 23	ridge axis central volcanic high	5 samples basalt + minor glass & chips + mud
73	0600h-0900h	MGM transit 25nm	Axis tie line to Hayes FZ	Aphanitic basalts.
74	0900h-1300h	Dredge # 24	MAR-Hayes FZ RTI west	13 samples basalt + minor glass + mud
75	1300h-1500h	mechanical work	engine R & R	Plagio-phyric basalts.
76	1500h-1700h	MGM transit 20nm	D-24 to D-25	
77	1700h-2100h	Dredge # 25	Hayes Fz west scarp (D-2,3)	31 pieces of metamorphosed plutonic rocks w/gabbro

N	Label	A	B	C	D
78		2100h-2300h	MGM transit 25nm	D-245 to D-26	dolerite, amphibolites & serpentinized-peridotite
79		2300h-2400h	Dredge #26	south wall west end Hayes FZ	mud & few rock chips
80	11/2/90	0000h-0400h	contin. Dredge #26		
81		12 hr cut	MGM survey 120nm	south wall of Hayes FZ	
82		0400h-0500h	MGM transit 10nm	D-26 to D-27	
83		0500h-0800h	Dredge #27	north wall of Hayes FZ	basalt fragments in mud.
84		0800h-1200h	MGM transit 30nm		
85		1200h-1700h	Dredge #28	MAR-Hayes FZ RTI east	87 samples of fresh basalts + glass & chips
86		1700h-2100h	MGM transit 40nm		plagiophyric and mixture of phyrlic/aphanitic
87		2100h-2400h	Dredge #29	south wall Hayes FZ east end	mud only
88	11/3/90	0000h-0400h	MGM transit 40nm	along south wall of Hayes FZ	
89		0400h-0800h	Dredge #30	south wall central Hayes FZ	62 pieces of altered dolerite, basalt, dolerite & basalt breccia
90		0800h-1500h	MGM survey 80nm	Hayes-Petrov eastern tie line	plagioclase phenocrysts; some metamorphism
91		1500h-1900h	Dredge #31	axial high (old site D-22)	basalt chips in mud
92		1900h-2400h	MGM survey 140nm	Hayes-Petrov eastern tie line	plagioclase and olivine phyrlic
93	11/4/90	0000h-1300h	contin. MGM survey		
94		1300h-1700h	Dredge #32	eastern Petrov FZ - south wall	1 sample - breccia w/dolerite frag. + mud
95		1700h-1900h	transit 15 nm		
96		1900h-2400h	Dredge #33	MAR north of Petrov FZ	mud only
97	11/5/90	0000h-0100h	transit 6 nm		
98		0100h-0700h	Dredge #34	MAR north of Petrov - west wall	mud with glass fragments.
99		0700h-1300h	MGM survey 65nm	tie line east side of surveys	
100		1300h-1600h	Dredge #35	Ridge axis south of Petrov (D-6)	46 samples of basalts w/ & w/o glass + mud
101		1600h-1900h	MGM survey 30nm	tie line into Atlantis FZ area	volcanitic, aphanitic
102		1900h-2300h	Dredge #36	Ridge axis north of Atlantis FZ	12 samples of basalt (pillows)
103		2300h-2400h	transit <10nm		with large plagioclase phenocrysts and xenocrysts
104	11/6/90	0000h-0400h	Dredge #37	MAR-Atlantis FZ RTI east	mud w/few rock chips
105		0400h-0500h	transit <10nm	D-35 to D-36	
106		0500h-1200h	Dredge #38	east Atlantis FZ-north wall-ICH	small basalt fragments in mud
107		1200h-1300h	transit <10nm		
108		1300h-1700h	Dredge #39	east Atlantis FZ-south wall-RTI	mud only
109		1700h-1800h	transit <10nm		
110		1900h-2200h	Dredge #40	central Atlantis FZ - south wall	1 small sample of basalt w/min crusts
111		2200h-2400h	transit <10nm	plus survey	with plagioclase and olivine microphenocrysts
112	11/7/90	0000h-0400h	Dredge #41	central Atlantis FZ - north wall	22 pieces of peridotite, partially serpentinized
113		0400h-0500h	transit <10nm		serpentine/ultramafic layers
114		0500h-0700h	Dredge #42	east Atlantis FZ-north wall-ICH	mud only
115		0700h-0900h	winch repairs		
116		0900h-1600h	contin. Dredge #42		

	Label	A	B	C	D
117		1600h-1700h	transit <10nm		
118		1700h-2100h	Dredge #43	western Atlantis FZ - south wall	mud only
119		2100h-2400h	transit 15 n.m.		
120	11/8/90	0000h-0300h	Dredge #44	western Atlantis FZ - south wall	1 large ferro-gabbro +
121		0300h-0500h	transit - 10 n.m.		6 small frag. gabbro/ferro-gabbro
122		0500h-0900h	Dredge #45	western Atlantis FZ - MAR RTI	85 pieces of basalt & andesitic basalt + glass
123		0900h-1000h	transit - 10 n.m.		1 flow unit & 1 pillow unit
124		1000h-1300h	Dredge #46	ridge axis south of Atlantis FZ	2 samples basalt + glass&basalt fragments
125		1200h-2400h	MGM survey 1397nm	transit to Barbados @ 11 kts	with some plagioclase phenocrysts
126	11/9/90	0000h-2400h	contin. MGM transit	transit to Barbados @ 11 kts	
127	11/10/90	0000h-0800h	contin. MGM transit	transit to Barbados @ 11 kts	
128		0800h-1800h	engine repairs		
129		1800h-2400h	contin. MGM transit	transit to Barbados @ 11 kts	
130	11/11/90	0000h-0800h	contin. MGM transit	transit to Barbados @ 11 kts	
131		0800h-1800h	engine repairs		
132		1800h-2400h	contin. MGM transit	transit to Barbados @ 11 kts	
133	11/12/90	0000h-2400h	contin. MGM transit	transit to Barbados @ 11 kts	
134	11/13/90	0000h-2400h	contin. MGM transit	transit to Barbados @ 11 kts	
135	11/14/90	0000h-2400h	contin. MGM transit	transit to Barbados @ 11 kts	
136	11/15/90	0000h-0800h	contin. MGM transit	transit to Barbados @ 11 kts	
137		0800h	Arrival	Bridgetown, Barbados	

## APPENDIX 3

### GEOPHYSICAL MEASUREMENT AND GEOLOGIC SAMPLING SYSTEMS

Geophysical systems on the ship were all provided by the Soviets. The bathymetric swath-mapping system and GPS/transit satellite navigation systems are now standard equipment on the RV Petrov. Magnetometer and gravity systems were provided by other institutions of the USSR Academy of Sciences for this cruise.

#### 1. Multibeam bathymetric mapping system

- a. ECHOS 625 model 4630 built in Finland by Hollming Ltd.\*  
similar to the U.S. Seabeam system.
- b. operator - Natalya Turko, Institute of Geology.  
assistant - Yecaterina Pavlenko, Institute of Geology.
- c. 15 beams with 4.3 degree (across axis) and 2.5 degree (along axis) dimensions.
- d. 12 kHz frequency with 1, 3, or 10 ms pulse lengths.
- e. operating depths of 100m to 4000+m
- f. swath coverage = 40 degrees = 70% water depth.
- g. real-time swath, strip plotting using 10" Benson strip plotter.\*
- h. data logging on EC-1011C (main) computer and IBM PC-AT with GF-3 format.
- i. ETAC bathymetry system (12k Hz) for single-beam data and analog display.\*
- j. see Appendix 4 for more details.

#### 2. Gravity system

- a. 3 - GMN-K 96 spring-balance beam type systems on gyro platforms.
- b. 1- forward-directed and 2 aft-directed beams for calc. cross coupling correction.
- c. developed and build at USSR Academy of Sciences Institute of Physics of the Earth.
- d. operator: Dr. Vitaliy Korenfeld, Inst. Physics of the Earth.  
assistants: Mr. Alexander Sindyukov and Mr. Yuri Konoplev, Inst. Physics of the Earth.
- e. 0.5 sec. recording with 1 min. avg. for all three meters recorded on tape.
- f. sensitivity = ? mgal.
- g. preliminary estimate of error = ? mgal.
- h. recorded on SORAM PC-XT computer built in Hungary(?).\*

#### 3. Magnetometer system

- a. optical-pumped Cesium magnetometer
- b. built at USSR Academy of Sciences Institute of Terrestrial Magnetism, Moscow
- c. operator: Vladimir Mayorshin, Inst. of Terrestrial magnetism  
assistant: Nikolai Ostroukhov, Inst. of Terrestrial Magnetism
- d. 180m towing cable
- e. 10 sec. sampling rate
- f. hand digitized at 1 minute interval  
working to get digital logging, but there was limited access to main computer logging facility

#### 4. Navigation system

- a. Magnavox MX5400 Global Positioning System (GPS) satellite receiver.\*  
no digital link to NAVOS - 625 system until Dec. 1990.
- b. Magnavox Transit Satellite positioning system.\*
- c. NAVOS - 625 integrated navigation system  
with ship's gyro, speed log, and satellite system plus Loran-C where possible.
- d. digital recording in main computer system (EC-1011).

#### 5. Deep-Sea Winch and Barrel Dredge Rock Sampling System

- a. 10 tonne Hagglands deep-sea winch  
w/series 84 type 84-25100 high-torque hydraulic motor.
- b. large barrel dredge (approx. 1m x 1.5m) with small tube dredge (approx. 0.2m x 0.5m).

\* Use of trade names is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

**APPENDIX 4**

**MULTIBEAM BATHYMETRIC SWATH-MAPPING SYSTEM - ECHOS-625 MODEL 4630**

**Builder:** Hollming Ltd., Finland, 1984  
**Ships:** RV A. Boris Petrov, RV A. Nikolaj Strakhov, and RV A. M.A. Lavrentyev

**Receiving Subsystem:**

<b>SONAR CHARAC- TERISTICS</b>	Frequency.....	12 kHz
	Pulse Length.....	1, 3, or 10 ms
	Transmitting Interval.....	10 sec.
	Power.....	200W or 2 kW
	Sounding Depth.....	100m - 4000+m
	Bottom Width coverage.....	40 deg.,70% w.d.
<b>ARRAY DESIGN</b>	<b>Transmitting Array</b>	
	Length.....	1620 mm
	Number of Projectors.....	12 x 1
	Beam Dimensions.....	64 deg. x 4.3 deg.
	<b>Receiving Array</b>	
	Length.....	3456 mm
<b>FORMED BEAMS</b>	Number of Hydrophones.....	36 x 3 (108)
	Beam Dimensions.....	2.5 deg. x 60 deg.
	<b>Digital Beam forming</b>	
	Number of Beams.....	15
	Beam Dimensions.....	2.5 deg. x 4.3 deg.
	Beam Spacing.....	3 deg.
	<b>Analog Beam forming</b>	
	Number of Beams.....	1
	Beam Dimensions.....	9.2 deg. x 4.3 deg.

**Processing Subsystem:**

- ANALOG BEAM**
  - . Echograph recording of the analog beamformer generated echo pulses (non-compensated vertical beam).
  - . Digitizer digital display of the depth on the non-compensated vertical beam.
  - . Acoustic device acquisition of the underwater sound pulses.
  
- NARROW BEAM**
  - . Line Scan Recorder recording of echo pulses from any of the 15 digitally-formed narrow beams (pitch and roll corrected).
  
- MULTI-BEAM**
  - . Vertical Reference based digital pitch and roll angle compensation
  - . Navigation system generated time (GMT), position (LAT,LON), ship (SPD,HDNG), and line (DA,DC,DE) information included.
  - . Color Video Monitor display of the bottom profile. Numerical data display or graphical 3-dimensional display can be selected. Graphical beam data display off-line option available.
  - . Magnetic tape transport recording of raw pulse data or final echo-sounding data. Repeating possibility from magnetic tape.
  
- REAL TIME DATA LOGGING**
  - . Logging Computer acquisition and storage of analog beam and multi-beam echo-sounding data into standard formatted (GF-3) data files.
  - . Processing Computer slant-range correction and depth-contour chart generation on flat-bed plotter.
  - . Local Area Network access to the Logging Computer State Table holding the latest echo-sounding and other environmental data.

APPENDIX 5

FORMATS FOR DIGITAL DATA

1. Navigation Data

a. in GF3 format = "NS" format

CYCLE PARAMETERS:		FORMAT
1)	NARE2N1N NAVIGATION REPORT TYPE	I2 (6=SAT.FIX)
2)	DATE5N1N DAY, D	A4
3)	TIME5N1N TIME, H,MIN,S	A6
4)	LATD5N1N SYSTEM LATITUDE, DEG	I4
5)	LATM5N1N SYSTEM LATITUDE, MIN	F6.3
6)	LOND5N1N SYSTEM LONGITUDE, DEG	I4
7)	LONM5N1N SYSTEM LONGITUDE, MIN	F6.3
8)	LATD5N2N RAW NAV LATITUDE, DEG	I4
9)	LATM5N2N RAW NAV LATITUDE, MIN	F6.3
10)	LOND5N2N RAW NAV LONGITUDE, DEG	I4
11)	LONM5N2N RAW NAV LONGITUDE, MIN	F6.3
12)	LATD5N3N FIX LATITUDE, DEG	I4
13)	LATM5N3N FIX LATITUDE, MIN	F6.3
14)	LOND5N3N FIX LONGITUDE, DEG	I4
15)	LONM5N3N FIX LONGITUDE, MIN	F6.3
16)	LATD5N4N NEW LATITUDE, DEG	I4
17)	LATM5N4N NEW LATITUDE, MIN	F6.3
18)	LOND5N4N NEW LONGITUDE, DEG	I4
19)	LONM5N4N NEW LONGITUDE, MIN	F6.3
20)	LATD5N5N OLD LATITUDE, DE	I4
21)	LATM5N5N OLD LATITUDE, MIN	F6.3
22)	LOND5N5N OLD LONGITUDE, DEG	I4
23)	LONM5N5N OLD LONGITUDE, MIN	F6.3
24)	SSPD2N1X SYSTEM SPEED, KN	F4.1
25)	DIRT5N1N SYSTEM HEADING, DEG	F6.1
26)	DRSP2N1N DRIFT SPEED, KN	F4.1
27)	DIRT5N2N DRIFT HEADING, DEG	F6.1
28)	LINA2N1N LINE NAME, -	A8
29)	DIST2N1N DIST ALNG LINE FR START, KM	F8.3
30)	DIST2N2N DISTANCE ACROSS LINE, KM	F8.3
31)	DIST2N3N DIST ALNG LINE TO END, KM	F8.3
32)	DIRT5N3N GYRO HEADING, DEG	F6.1
33)	DELT2N1N DELTA X, M	I6
34)	DELT2N2N DELTA Y, M	I6
35)	DELT2N3N DELTA Z, M	I6
36)	ECCN2N1N RECIPROCAL OF FLATTENING, -	I6
37)	SMAX2N1N SEMIMAJOR AXIS, M	I6
38)	STDV2N1N FIX LATIT STAND DEV, M	I4
39)	STDV2N2N FIX LONGIT STAND DEV, M	I4
40)	LITY2N1N LINE TYPE, CODE	I2
41)	DATF2N1N DATUM FLAG, CODE	I2
42)	STDV2N3N SYST LAT NEW STAND DEV, M	I4
43)	STDV2N4N SYST LONG NEW STAND DEV, M	I4
44)	STDV2N5N SYST LAT OLD STAND DEV, M	I4
45)	STDV2N6N SYST LONG OLD STAND DEV, M	I4
46)	CAUP2N1N CAUSE TO UPDATE, CODE	I2
47)	SHNU2N1N SHOT NUMBER, -	I4
48)	MINS5N1N TIME SINCE LAST FIX, MIN	I4
49)	WATR2N1N DISTANCE IN WATER TRACK, NM	I4
50)	SPTY2N1N SPEED TYPE, CODE	I2
51)	HETY2N1N HEADING TYPE, CODE	I2
52)	RADF2N1N RAD NAV USE FLAG, -	I2

## 2. Multibeam Bathymetric Data

a. in GF3 format = "MB" format

CYCLE PARAMETERS:		FORMAT
1) DATE5B1N	SOUNDING DATE, D	A4
2) TIME5B1N	SOUNDING TIME, H,MIN,S	A6
3) LATD5B1N	SYSTEM LATITUDE, DEG	I4
4) LATM5B1N	SYSTEM LATITUDE, MIN	F6.3
5) LOND5B1N	SYSTEM LONGITUDE, DEG	I4
6) LONM5B1N	SYSTEM LONGITUDE, MIN	F6.3
7) SSPD2B1N	SYSTEM SPEED, KN	F4.1
8) DIRT5B1N	SYSTEM HEADING, DEG	F6.1
9) DIST2B1N	DIST ALNG LINE FR START, KM	F8.3
10) DIST2B2N	DISTANCE ACROSS LINE, KM	F8.3
11) DIST2B3N	DIST ALNG LINE TO END, KM	F8.3
12) DIST2B4N	DIST FROM START POINT, KM	F8.3
13) DEPH5B1D	BEAM 1 DEPTH, M	I4
14) DEPH5B2D	BEAM 2 DEPTH, M	I4
15) DEPH5B3D	BEAM 3 DEPTH, M	I4
16) DEPH5B4D	BEAM 4 DEPTH, M	I4
17) DEPH5B5D	BEAM 5 DEPTH, M	I4
18) DEPH5B6D	BEAM 6 DEPTH, M	I4
19) DEPH5B7D	BEAM 7 DEPTH, M	I4
20) DEPH5B8D	BEAM 8 DEPTH, M	I4
21) DEPH5B9D	BEAM 9 DEPTH, M	I4
22) DEPH5BAD	BEAM 10 DEPTH, M	I4
23) DEPH5BBD	BEAM 11 DEPTH, M	I4
24) DEPH5BCD	BEAM 12 DEPTH, M	I4
25) DEPH5BDD	BEAM 13 DEPTH, M	I4
26) DEPH5BED	BEAM 14 DEPTH, M	I4
27) DEPH5BFD	BEAM 15 DEPTH, M	I4
28) DIST2B5N	B1 DIST FROM CENTRAL LINE,M	I5
29) DIST2B6N	B2 DIST FROM CENTRAL LINE,M	I5
30) DIST2B7N	B3 DIST FROM CENTRAL LINE,M	I5
31) DIST2B8N	B4 DIST FROM CENTRAL LINE,M	I5
32) DIST2B9N	B5 DIST FROM CENTRAL LINE,M	I5
33) DIST2BAN	B6 DIST FROM CENTRAL LINE,M	I5
34) DIST2BBN	B7 DIST FROM CENTRAL LINE,M	I5
35) DIST2BCN	B8 DIST FROM CENTRAL LINE,M	I5
36) DIST2BDN	B9 DIST FROM CENTRAL LINE,M	I5
37) DIST2BEN	B10 DIST FR CENTRAL LINE, M	I5
38) DIST2BFN	B11 DIST FR CENTRAL LINE, M	I5
39) DIST2BGN	B12 DIST FR CENTRAL LINE, M	I5
40) DIST2BHN	B13 DIST FR CENTRAL LINE, M	I5
41) DIST2BIN	B14 DIST FR CENTRAL LINE, M	I5
42) DIST2BJN	B15 DIST FR CENTRAL LINE, M	I5
43) SVEL2B1D	SOUND VELOCITY, M/S	F6.1
44) PITC2B1N	PITCHING ANGLE, DEG	F4.1
45) ROLL2B1N	ROLLING ANGLE, DEG	F4.1

APPENDIX 6

R/V AKADEMIK BORIS PETROV-16 (ABP-16) DREDGE STATIONS

Station number: **ABP-16-1**  
 Date: 16 Oct 1990  
 Time: 1517z-1950z  
 Lat/Long: 33°38.86'n, 3743.95'w to 33°33.75'n, 3742.64'w  
 Water depth: 3238m to 2935m  
 Sample Site: **Hayes Fracture Zone:** on north wall of tilted block within east end of fracture zone just east of ridge-transform intersection.  
 Sampling device: Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
 Number of samples: 49 rock samples plus numerous fragments. Sediment.  
 Type of samples: Dolerites and gabbros plus some basalt. Several large boulders showing a contact between gabbro and dolerite. Interpreted as a being from a contact zone between gabbro and an overlying sheeted-dike complex. Gabbro is evidently intrusive into the dikes in many cases. These samples indicate that the layer 2-layer 3 boundary may be exposed along the south wall of the Hayes Fracture Zone. Some samples brecciated with greenschist metamorphic grade and some shearing with slickensided shear planes. Deep-sea mud within small dredge.  
 Remarks: A very fine dredge collection of metamorphic rocks from fracture zone Dredged to southeast up north-facing scarp on tilted block. Thin-sections made onboard ship of samples 1-1F, 1-1I, 1-1J, 1-2B, 1-2C, 1-3, 1-11, 1-12, 1-14, 1-15, 1-16, 1-17, 1-19, 1-21, 1-22, 1-33, 1-41, 1-43, and 1-48. Samples split between U.S. and Soviet scientists. Mud samples to U.S.

Station number: **ABP-16-2**  
 Date: 17 Oct 1990  
 Time: 1259z to 1811z  
 Sample Site: **Hayes Fracture Zone:** On north-facing wall at west end of fracture zone just east of ridge-transform intersection and within active transform.  
 Lat/Long: 33°40.46'n, 3852.55'w to 33°37.18'n, 3852.72'w  
 Water depth: 3448m to 1576m  
 Sampling device: Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
 Number of samples: None.  
 Remarks: Dredge anchored on bottom and finally lost when cable broke at dredge.

Station number: **ABP-16-3**  
 Date: 17-18 Oct 1990  
 Time: 2000z to 0110z  
 Sample Site: **Hayes Fracture Zone:** On north-facing wall at west end of fracture zone just east of ridge-transform intersection and within active transform. Repeat of dredge site ABP-16-2  
 Lat/Long: 33°42.37'n, 3851.97'w to 33°40.79'n, 3849.20'w  
 Water depth: 3818m to 3606m  
 Sampling device: Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
 Number of samples: Sediment only.  
 Type of samples: Deep-sea mud.  
 Remarks: Dredge may never have gotten out of mud at base of scarp. Mud sample to U.S. scientists.

Station number: **ABP-16-4**  
Date: 19 Oct 1990  
Time: 0013z to 0520z  
Sample Site: **Petrov Fracture Zone:** On west-facing scarp of tilted block within eastern end of transform zone just east of ridge-transform intersection. Perhaps from talus ramp in eastern nodal basin.  
Lat/Long: 31°08.69'n, 41°12.29'w to 31°08.77'n, 41°12.21'w  
Water depth: 3220m to 3180m  
Sampling device: Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
Number of samples: Over 200 rock samples plus numerous fragments. Sediment.  
Type of samples: Basalt and basaltic glass. Petrographically, this appears to be typical "MORB". Includes suites of Olivine-phyric, Plagioclase-phyric basalts, some Olivine/plagioclase-phyric basalts, and some aphyric basalts. plenty of glass. A few samples contain large olivine and plagioclase megacrysts.  
Remarks: Deep-sea mud within small dredge.  
A very fine, large dredge collection of basaltic rocks from fracture zone Dredged in a loop on sea floor and not just one direction.  
Samples split between U.S. and Soviet scientists. Mud samples to U.S. scientists.

Station number: **ABP-16-5**  
Date: 19 Oct 1990  
Time: 0635z to 1000z  
Sample Site: **Petrov Fracture Zone:** On north-facing scarp of axial high at nodal deep at the ridge-transform intersection at west end of transform zone.  
Lat/Long: 31°07.74'n, 41°23.56'w to 31°06.85'n, 41°24.59'w  
Water depth: 3400m to 3279m  
Sampling device: Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
Number of samples: 12 rock samples plus numerous basalt and glass fragments. Sediment.  
Type of samples: Basalt and basaltic glass. Plenty of glass. Fresh, aphyric, glassy basalt. Numerous slabs and "toes". It appears to be sampled from a large, collapsed lava tube or lake. Most samples are fragile and were bagged without cutting to preserve glass. This suite of rocks is typical of very recent "zero-age" basalts and indicates recent volcanism just south of Petrov FZ. Deep-sea mud.  
Remarks: A good (small) collection of fresh basaltic rocks from axial high.  
Samples split between U.S. and Soviet scientists. Mud samples to U.S. scientists.

Station number: **ABP-16-6**  
Date: 19 Oct 1990  
Time: 1546z to 1900z  
Sample Site: **MAR - Axial High.** North end of first ridge segment north of Atlantis FZ.  
Lat/Long: 30°23.52'n, 41°55.77'w to 30°24.45'n, 41°56.91'w  
Water depth: 3250m to 2990m  
Sampling device: Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
Number of samples: 67 samples - a medium-sized collection of rocks. No sediment.  
Type of samples: Very fresh basalt with glass, including pieces that look like fragments of lava toes, slab flows, lava lake crusts, and pillows. Abundant slabby glass crusts of the kind usually recovered in collapsed lava lakes on the East Pacific Rise. Some more massive pillow fragments which may be slightly older. Most samples are sparsely plagioclase phyric, but thin sections show olivine microphenocrysts some intergrown with plagioclase. Very glassy samples.  
Remarks: A very fine dredge collection of basaltic rocks from axial high.  
This material may be indicative of relatively recent and voluninous eruption near the axial high between Petrov and Atlantis Fracture Zones.  
Thin-sections made onboard ship of samples 6-22, 6-34, and 6-67.  
Samples split between U.S. and Soviet scientists.

**Station number:** ABP-16-7  
**Date:** 19 Oct 1990  
**Time:** 2028z to 2300z  
**Sample Site:** MAR - Axial High. Second ridge segment north of Atlantis Fracture Zone.  
**Lat/Long:** 30°35.05'n, 41°51.51'w to 30°34.47'n, 41°52.88'w  
**Water depth:** 3440m to 3319m  
**Sampling device:** Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
**Number of samples:** 9 samples including long pillow tube fragment.  
**Type of samples:** Fresh basalt with glass, but not as fresh as rocks from Dredge ABP-16-6. Striated glassy pillow surfaces with large plagioclase phenocrysts and xenocrysts(?). Rusty colored glass. Two main petrographic types of basalts: plagioclase-phyric and sparsely phyric to aphyric. Thin sections show olivine microphenocrysts in the phyric basalt in addition to 10-15% plagioclase phenocrysts, and some olivine-plagioclase intergrowths. This suite of rocks appears to be normal "MORB".  
**Remarks:** 0.3m long section of a pillow tube that was broken into 3 pieces. Fine, small dredge collection of plagioclase-phyric basaltic rocks from axial high. Dredged to southeast up west side of axial high. Thin sections made onboard ship. Samples split between U.S. and Soviet scientists.

**Station number:** ABP-16-8  
**Date:** 19-20 Oct 1990  
**Time:** 2347z to 0350z  
**Sample Site:** MAR - Axial High. Third ridge segment north of Atlantis Fracture Zone.  
**Lat/Long:** 30°42.87'n, 41°44.88'w to 30°45.16'n, 41°44.17'w  
**Water depth:** 3600m to 3250m  
**Sampling device:** Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
**Number of samples:** None.  
**Remarks:** Dredge anchored on bottom. Dredge and cable all lost when wire was run off winch drum.

**Station number:** ABP-16-9  
**Date:** 22-23 Oct 1990  
**Time:** 2311z to 0200z  
**Sample Site:** MAR - Axial High. Second ridge segment north of Petrov Fracture Zone.  
**Lat/Long:** 31°21.42'n, 41°06.70'w to 31°21.61'n, 41°06.27'w  
**Water depth:** 3232m to 3140m  
**Sampling device:** Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
**Number of samples:** Small basaltic fragments and glass fragments in mud.  
**Type of samples:** Palagonitized basalt with glass. Sparsely plagioclase phyric.  
**Remarks:** Dredging to southeast up the west side of axial high. Rock fragments in mud within the small tube dredge only. Rock and mud samples all to U.S. scientists.

**Station number:** ABP-16-10  
**Date:** 23 Oct 1990  
**Time:** 0300z to 0608z  
**Sample Site:** MAR - Axial High. Second ridge segment north of Petrov Fracture Zone. repeat dredge site ABP-16-9.  
**Lat/Long:** 31°21.42'n, 41°05.52'w to 31°21.52'n, 41°05.13'w  
**Water depth:** 3208m to 3139m  
**Sampling device:** Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
**Number of samples:** 11 samples plus 2 bags of basalt chips and glass fragments.  
**Type of samples:** Plagioclase-phyric basalt with glass. Some very fresh pieces. Thin sections show olivine in addition to plagioclase and some olivine/plagioclase glomerocrysts. The older samples show some palagonitization of the glass.  
**Remarks:** Drifted to east as dredge went down and then dredged to northwest along east edge of axial high. Thin section made onboard ship of 10-8a (in Houston). All samples divided into groups by size and alteration and then groups of rock samples split between U.S. and Soviet scientists. Mud to U.S. scientists.

Station number: **ABP-16-11**  
Date: 24 Oct 1990  
Time: 0039z to 0252z  
Sample Site: **MAR - Axial High.** Third ridge segment north of Petrov Fracture Zone.  
Lat/Long: 31°29.19'n, 40°59.43'w to 31°30.35'n, 40°00.49'w  
Water depth: 2963m to 2930m  
Sampling device: Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
Number of samples: 12 samples plus 2 bags of assorted glass fragments and  
1 bag of basalt chips and glass fragments.  
Type of samples: Aphyric basalt with glass and with some plagioclase phenocrysts.  
Thin sections show olivine and plagioclase microphenocrysts and intergrowths.  
Olivine is the dominant phase, appearing as abundant quench microlites in the  
groundmass as well as in microphenocrysts and glomerocrysts. This appears to be  
a more mafic basalt in comparison to the samples further to the south.  
Remarks: Dredged to northwest along the east edge of axial high.  
Thin sections made onboard ship.  
Rock samples split between U.S. and Soviet scientists. mud to U.S. scientists.

Station number: **ABP-16-12**  
Date: 24-25 Oct 1990  
Time: 2134z to 0050z  
Sample Site: **MAR - Axial High.** Fourth ridge segment north of Petrov Fracture Zone.  
Lat/Long: 31°33.22'n, 40°53.38'w to 31°34.66'n, 40°54.88'w  
Water depth: 3274m to 3200m  
Sampling device: Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
Number of samples: 14 samples plus 4 bags of assorted glass fragments (2 high grade; 2 low grade)  
Type of samples: Basalt w/glass and with some plagioclase and olivine phenocrysts.  
Thin sections show olivine dominant, as in dredge ABP-16-11. This is consistent  
with the more mafic compositions going north from Petrov FZ.  
Deep-sea sediment in small tube dredge.  
Remarks: Dredged to northwest along the east edge of axial high.  
Thin sections made onboard ship of 12-1 and 12-2.  
Rock samples split between U.S. and Soviet scientists. Mud to U.S. scientists.

Station number: **ABP-16-13**  
Date: 25 Oct 1990  
Time: 1820z to 2100z  
Sample Site: **MAR - Axial High.** "Zero-offset" transform between 4th and 5th ridge segments  
north of Petrov Fracture Zone.  
Lat/Long: 31°38.61'n, 40°46.20'w to 31°39.66'n, 40°46.75'w  
Water depth: 3521m to 3452m  
Sampling device: Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
Number of samples: No samples.  
Remarks: Dredged to northwest along the east edge of axial high. Did not remain on  
bottom long enough to acquire samples. Moved only 350m over ground.

Station number: **ABP-16-14**  
Date: 26 Oct 1990  
Time: 1636z to 1900z  
Sample Site: **MAR - Axial High.** Fifth ridge segment north of Petrov Fracture Zone.  
Eastern edge of rift valley just north of "zero" (small) offset transform.  
Lat/Long: 31°45.71'n, 40°36.30'w to 31°45.97'n, 40°36.38'w  
Water depth: 3699m to 3663m  
Sampling device: Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
Number of samples: 4 bags of assorted basalt chips & glass fragments. Sediment.  
Type of samples: Basalt fragments and glass within deep-sea sediment in small tube dredge.  
Thin section shows basalt is variolitic with clusters of olivine microphenocrysts  
and abundant olivine in the glass.  
Remarks: Dredged to north for only 350m along the east flank of axial high.  
Rock samples split between U.S. and Soviet scientists. Mud to U.S. scientists.

Station number: **ABP-16-15**  
Date: 27 Oct 1990  
Time: 1635z to 1930z  
Sample Site: **MAR - Axial High.** Fifth ridge segment north of Petrov Fracture Zone.  
West side of rift valley.  
Lat/Long: 31°53.12'n, 40°35.32'w to 31°53.33'n, 40°34.76'w  
Water depth: 3000m to 2966m  
Sampling device: Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
Number of samples: 5 rock samples plus mud in small tube dredge.  
Type of samples: Basalt with plagioclase and olivine phenocrysts(?). Very weathered.  
Deep-sea sediment.  
Remarks: Dredged to north for about 1000m along the east flank of axial high.  
Rock samples split between U.S. and Soviet scientists. Mud to U.S. scientists.

Station number: **ABP-16-16**  
Date: 28 Oct 1990  
Time: 1334z to 1545z  
Sample Site: **MAR - Axial High.** Sixth ridge segment north of Petrov Fracture Zone.  
West side of rift valley.  
Lat/Long: 31°59.16'n, 40°27.53'w to 31°59.63'n, 40°27.75'w  
Water depth: 2662m to 2652m  
Sampling device: Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
Number of samples: 7 rock samples and 2 bags of fragments plus mud in small tube dredge.  
Type of samples: Basalt with plagioclase phenocrysts. Deep-sea sediment.  
Remarks: Dredged to northeast for about 600m along the top of axial high.  
Rock samples split between U.S. and Soviet scientists. Mud to U.S. scientists.

Station number: **ABP-16-17**  
Date: 29 Oct 1990  
Time: 0816z to 1100z  
Sample Site: **MAR - Axial High.** Seventh ridge segment north of Petrov Fracture Zone.  
West side of rift valley.  
Lat/Long: 32°02.43'n, 40°22.95'w to 32°04.18'n, 40°22.17'w  
Water depth: 3001m to 2832m  
Sampling device: Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
Number of samples: 3 rock samples and 2 bags of fragments plus mud in small tube dredge.  
Type of samples: Aphanitic and glassy basalt. Deep-sea sediment.  
Olivine microphenocrysts and glomerocrysts (8-10%) in a matrix of variolitic glass seen in thin sections.  
Remarks: Dredged to northeast for about 1400m along the west flank of axial high.  
Small set of samples in small tube dredge.  
Thin sections made onboard ship of 17-1,17-2,17-3.  
Rock samples split between U.S. and Soviet scientists. Mud to U.S. scientists.

Station number: **ABP-16-18**  
Date: 30 Oct 1990  
Time: 0454z to 0600z  
Sample Site: **MAR - Axial High.** Seventh ridge segment north of Petrov Fracture Zone.  
West side of rift valley.  
Lat/Long: 32°10.02'n, 40°19.84'w to 32°10.03'n, 40°19.85'w  
Water depth: 3500m  
Sampling device: Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
Number of samples: No samples.  
Remarks: Problem with winch. Operations stopped with 1080m wire out.

Station number: **ABP-16-19**  
Date: 30 Oct 1990  
Time: 0900z to 1120z  
Sample Site: **MAR - Axial High.** Seventh ridge segment north of Petrov Fracture Zone.  
West side of rift valley. Same location as ABP-16-18.  
Lat/Long: 32°09.05'n, 40°19.61'w to 32°09.75'n, 40°20.57'w  
Water depth: 3322m to 3175m  
Sampling device: Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
Number of samples: 6 small rock fragments within mud.  
Type of samples: Basalt with glass. Deep-sea sediment.  
Remarks: Dredged to northwest for about 750m along the east flank of axial high.  
Samples in small tube dredge only.  
Rock fragments split between U.S. and Soviet scientists. Mud to U.S. scientists.

Station number: **ABP-16-20**  
Date: 31 Oct 1990  
Time: 1152z to 1350z  
Sample Site: **MAR - Axial High.** Seventh ridge segment north of Petrov Fracture Zone.  
West side of rift valley.  
Lat/Long: 32°13.66'n, 40°11.66'w to 32°13.88'n, 40°11.79'w  
Water depth: 3200m to 3200m  
Sampling device: Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
Number of samples: Mud only.  
Type of samples: Deep-sea sediment.  
Remarks: Dredged to northwest for about 600m along the east flank of axial high.  
Mud sample in small tube dredge only. On bottom only 20 min.  
Mud to U.S. scientists.

Station number: **ABP-16-21**  
Date: 31 Oct 1990  
Time: 1632z to 2025z  
Sample Site: **MAR - Axial High.** Eighth(?) ridge segment north of Petrov Fracture Zone.  
West side of rift valley.  
Lat/Long: 32°27.92'n, 40°06.55'w to 32°27.83'n, 40°06.11'w  
Water depth: 2888m to 2970m  
Sampling device: Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
Number of samples: No samples.  
Remarks: Dredge anchored to bottom and finally lost.

Station number: **ABP-16-22**  
Date: 1 Nov 1990  
Time: 0104z to 0245z  
Sample Site: **MAR - Axial High.** Ninth(?) ridge segment north of Petrov Fracture Zone.  
East side of rift valley.  
Lat/Long: 32°52.38'n, 40°40.15'w to 32°51.87'n, 39°38.83'w  
Water depth: 2360m to 2150m to 2223m  
Sampling device: Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
Number of samples: Mud only.  
Type of samples: Deep-sea sediment.  
Remarks: Dredged to southeast for about 800m over axial high.  
Mud sample in small tube dredge only. On bottom only 30 min.  
Mud to U.S. scientists.

Station number: **ABP-16-23**  
Date: 1 Nov 1990  
Time: 0705z to 0918z  
Sample Site: **MAR - Axial High.** Second ridge segment south of Hayes Fracture Zone.  
East side of rift valley.  
Lat/Long: 33°11.95'n, 39°11.44'w to 33°14.11'n, 39°10.32'w  
Water depth: 2702m to 2635m  
Sampling device: Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
Number of samples: 5 rock samples and two bags of rock fragments and glass. Mud.  
Type of samples: Aphanitic basalt with minor glass. Deep-sea sediment.  
Several large pillow fragments; most glass appeared to have spalled before recovery, and there is some palagonitization of remaining glass.  
Thin sections show microphenocrysts and glomerocrysts of olivine and plagioclase and more rarely of clinopyroxene/plagioclase.  
Mineralogically, this is relatively "more evolved" than basalts recovered to south.  
Remarks: Dredged to east-northeast for about 1000m along the west flank of axial high.  
Dredge was on bottom for about 30 minutes.  
Thin sections made onboard ship of samples 23-2, 23-3, 23-4, and 23-6.  
Rock samples split between U.S. and Soviet scientists. Mud to U.S. scientists.

Station number: **ABP-16-24**  
Date: 1 Nov 1990  
Time: 1324z to 1555z  
Sample Site: **MAR - Axial High.** First ridge segment south of Hayes Fracture Zone.  
Near ridge transform intersection and up east wall of rift valley.  
East side of rift valley.  
Lat/Long: 33°33.05'n, 39°01.24'w to 33°31.79'n, 38°59.28'w  
Water depth: 2169m to 2000m  
Sampling device: Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
Number of samples: 13 rock samples plus mud.  
Type of samples: Plagioclase-phyric basalts. Deep-sea sediment.  
Including plagioclase, olivine and clinopyroxene phenocrysts.  
Thin sections confirm presence of olivine and clinopyroxene or spinel.  
Two large pillow fragments and 11 smaller ones that are not fresh.  
Relatively older basalts than those found to south.  
Relatively evolved, like samples in ABP-23 but even older.  
Remarks: Dredge floated in water column as it moved east across axial high and then dredged to east for about 300m along the east flank of axial high and up the eastern rift wall. Dredge was on bottom for about 20 minutes.  
Rock samples split between U.S. and Soviet scientists. mud to U.S. scientists.

Station number: **ABP-16-25**  
Date: 1 Nov 1990  
Time: 2037z to 2345z  
Sample Site: **Hayes Fracture Zone.** Southern scarp of nodal deep at west end of Hayes FZ.  
Just east of rift valley on north-facing scarp of tilted block forming east rift wall.  
Same locale as dredge sites ABP-16-2 and ABP-16-3.  
Lat/Long: 33°40.05'n, 38°55.06'w to 33°38.45'n, 38°53.16'w  
Water depth: 3310m to 2478m  
Sampling device: Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
Number of samples: 31 rock samples and 6 bags of large cobbles, cobbles, and pebbles. plus mud.  
Type of samples: Metamorphosed plutonic rocks, including amphibolites, metagabbros/dolerites, and ultramafics. Includes some serpentinized peridotite, bornblende, chlorite.  
Some samples strongly deformed. Generally greenschist metamorphic grade.  
Deep-sea sediment.  
Remarks: Dredged to south-southeast up steep north-facing scarp. Dredge was on bottom for about 1 hour and 15 minutes. Thin sections made on board ship of samples 25-1, 25-2, 25-5, 25-6, 26-7, 25-8, 25-9, 25-10, 25-12, 25-13, 25-14, 25-15, 25-16, 25-17, 25-22, 25-23, 25-24, 25-25, 25-26, 25-27, and 25-28.  
Rock samples split between U.S. and Soviet scientists. Mud to U.S. scientists.

Station number: **ABP-16-26**  
Date: 2 Nov 1990  
Time: 0301z to 0630z  
Sample Site: **Hayes Fracture Zone.** South wall of transform zone.  
Midway between nodal deeps. South of dredge PD-12-2 (1989) on north wall.  
Lat/Long: 33°34.06'n, 38°28.17'w to 33°33.57'n, 38°25.94'w  
Water depth: 3821m to 3050m.  
Sampling device: Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
Number of samples: A few small rock fragments in mud.  
Type of samples: Basalt fragments. Deep-sea sediment.  
Remarks: Dredged to south-southeast up steep north-facing scarp.  
Dredge was floating near bottom for about one and a half hours, but it was probably only on bottom for a few minutes at base of scarp in mud.  
Samples only found in small pipe dredge.  
Mud to U.S. scientists.

Station number: **ABP-16-27**  
Date: 2 Nov 1990  
Time: 0757z to 1010z  
Sample Site: **Hayes Fracture Zone.** North wall of transform zone.  
At corner high just east of eastern nodal deep. Just east of dredge PD-12-2.  
Lat/Long: 33°37.01'n, 38°20.53'w to 33°38.29'n, 38°18.43'w  
Water depth: 3814m to 3700m  
Sampling device: Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
Number of samples: A few small rock fragments in mud.  
Type of samples: Basalt fragments. Deep-sea sediment.  
Remarks: Dredged to north-northeast up steep south-facing scarp. Dredge was on bottom for about 45 minutes with most of the time near base of scarp in mud.  
Samples only found in small pipe dredge. Mud to U.S. scientists.

Station number: **ABP-16-28**  
Date: 2 Nov 1990  
Time: 1458z to 1925z  
Sample Site: **MAR - Axial High.** First ridge segment north of Hayes FZ.  
Just north of nodal deep at east end of Hayes FZ.  
Lat/Long: 33°48.26'n, 37°45.78'w to 33°48.94'n, 37°41.38'w  
Water depth: 3414m to 2844m  
Sampling device: Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
Number of samples: 87 rock samples, 2 bags of rock chips, and 3 bags of "glass toes" plus mud.  
Type of samples: Fresh basalts w/glass and some older basalts. Fresh rock is plagioclase phyric. Older rock includes both phyric & aphyric material.  
Thin sections show olivine is abundant as microphenocrysts in all varieties.  
Large suite of fresh basalt samples including numerous pillow fragments and a large lava slab with drip marks (28-35).  
Samples 28-31 to 28-60 appear to be aphanitic basalts, but not cut or broken so phenocrysts if any are not known.  
Deep-sea sediment.  
Remarks: Dredged to east over axial high and continued to east rift wall scarp.  
Dredge was on bottom for about 2 and a half hours.  
Glass scraped off samples 16-28-1 to 16-28-7 and bagged separately.  
Prism cut from sample 28-35.  
Thin sections made onboard ship of samples.  
Rock samples split between Soviet and U.S. scientists. Mud to U.S. scientists.

Station number: **ABP-16-32**  
Date: 4 Nov 1990  
Time: 1647z to 1955z  
Sample Site: **Petrov Fracture Zone.** South wall of fracture zone east of eastern nodal deep.  
Lat/Long: 31°04.12'n, 4°00.25'w to 3°01.27'n, 4°58.43'w  
Water depth: 2400m to 1810m  
Sampling device: Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
Number of samples: 1 small rock sample and sediment sample.  
Type of samples: Basalt and glass(?) (hyaloclastite?) breccia. Deep-sea sediment.  
Remarks: Dredged to southeast up steep north-facing scarp. Dredge station started well to north of scarp and looped to east and then west as it moved south and finally intersected seafloor after one hour "near" bottom. Touched bottom only once, probably at water depth of about 2300m to 2400m.  
Breccia sample cut and split between Soviet and U.S. Scientists.  
Mud to U.S. Scientists.

Station number: **ABP-16-33**  
Date: 5 Nov 1990  
Time: 0019z to 0400z  
Sample Site: **MAR - Axial High.** First ridge segment north of Petrov Fracture Zone.  
East side of rift valley.  
Lat/Long: 31°16.43'n, 4°12.51'w to 3°14.86'n, 4°10.06'w  
Water depth: 3777m to 3463m  
Sampling device: Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
Number of samples: Mud only.  
Type of samples: Deep-sea sediment.  
Remarks: Dredged to southeast over axial high for distance of about 3000m.  
Dredge was on bottom for about 1 hour and 45 min.  
Mud sample only in small pipe dredge. Mud to U.S. scientists.

Station number: **ABP-16-34**  
Date: 5 Nov 1990  
Time: 0708z to 1000z  
Sample Site: **MAR - West Wall.** First ridge segment north of Petrov Fracture Zone.  
Lat/Long: 31°14.63'n, 4°12.81'w to 3°15.77'n, 4°14.30'w  
Water depth: 3200m to 2600m  
Sampling device: Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
Number of samples: Mud with glass fragments only.  
Type of samples: Basaltic glass and deep-sea sediment.  
Remarks: Dredged to north-northwest along and up east-facing scarp.  
Moved for distance of about 1300m over bottom with dredge.  
Dredge was on bottom for about 50 min.  
Mud sample only in small pipe dredge. Mud to U.S. scientists.

Station number: **ABP-16-29**  
Date: 3 Nov 1990  
Time: 0029z to 0310z  
Sample Site: **Hayes Fracture Zone.** South wall of transform zone south of first main ridge segment north of Hayes FZ.  
Just south of tilted block (dredge ABP-16-1 site) within transform zone.  
Lat/Long: 33°28.19'n, 37°49.24'w to 33°27.52'n, 37°47.08'w  
Water depth: 3383m to 3115m  
Sampling device: Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
Number of samples: Mud only.  
Type of samples: Deep-sea sediment.  
Remarks: Dredged to southeast up steep north-facing scarp over distance of about 1000m. Dredge was on bottom for about 40 minutes with most of the time near base of scarp in mud. Samples only found in small pipe dredge. Mud to U.S. scientists.

Station number: **ABP-16-30**  
Date: 3 Nov 1990  
Time: 0726z to 1110z  
Sample Site: **Hayes Fracture Zone.** South wall of transform zone at eastern nodal deep.  
Lat/Long: 33°35.31'n, 38°14.23'w to 33°31.87'n, 38°12.48'w  
Water depth: 2700m to 2400m  
Sampling device: Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
Number of samples: 62 rock samples, 2 bags of small rock fragments, 2 bags of chips and Mn crusts, and 2 bags of Mn crust & concretions, and sediment sample.  
Type of samples: Altered basalts, dolerites and dolerite/basalt breccias, and deep-sea sediment. Some breccias contained glass fragments. Most pieces were moderately to heavily weathered, obscuring the nature of metamorphism. Many samples contained plagioclase phenocrysts. Thin sections show basalts to be plagioclase phyric with quench olivine preserved in some samples.  
Remarks: Some good examples of metamorphism of upper crustal rocks. Dredged to southeast(east?) up steep north-facing scarp over distance of 250m and on bottom for about 13 minutes according to Soviet dredge log. Dredge may have been on bottom for as long as 1 hour, but log suggests most of the time it was in water column just north of scarp. There was 3800m of dredge wire out in a water depth of 3390m as the ship moved for a distance of 1.6 km to southeast. Dredge probably hit bottom at water depth of over 2600m. It became anchored for a short time and then pulled up as soon as it was freed. No note in Soviet log book of anchoring, but changes in water depth after dredge on bottom suggest it was stuck and changed course to free it. Thin sections made on board ship for samples: 30-1, 30-2, 30-3, 30-4, 30-5, 30-9, 30-11, 30-12, 30-13, 30-17, 30-18A, 30-18B, 30-20, 30-21, 30-22, 30-25, 30-31, 30-33, 30-34, 30-37, 30-38, 30-43, 30-45, 30-46, 30-47, 30-48, 30-53, 30-61. All rock samples and "fragment" bags split between U.S. and Soviet scientists. Mud to U.S. scientists.

Station number: **ABP-16-31**  
Date: 3 Nov 1990  
Time: 2000z to 2220z  
Sample Site: **MAR - Axial High.** Ninth(?) ridge segment north of Petrov Fracture Zone. East side of rift valley. Repeat at dredge site ABP-16-22.  
Lat/Long: 32°52.50'n, 39°40.01'w to 32°51.05'n, 39°38.40'w  
Water depth: 2321m to 2160m  
Sampling device: Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
Number of samples: Basalt chips in mud.  
Type of samples: Plagioclase and olivine phyric basalt. Deep-sea sediment. Thin section of 31-1 shows plagioclase and olivine phenocrysts and glomerocrysts in felted matrix of plagioclase microlites.  
Remarks: Dredged to southeast over axial high for distance of about 2000m. Dredge was on bottom for about one hour. Samples only in small pipe dredge. Rock chips split. Mud to U.S. scientists.

Station number: **ABP-16-35**  
Date: 5 Nov 1990  
Time: 1814z to 2012z  
Sample Site: **MAR - Axial High.** On north end of axial high of second ridge segment north of Atlantis Fracture Zone, but within overlap zone between second and third ridge segments. Just north of old site ABP-16-8.  
Lat/Long: 30°49.16'n, 41°45.30'w to 30°46.90'n, 41°45.10'w  
Water depth: 3387m to 3389m  
Sampling device: Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
Number of samples: 48 rock samples plus mud.  
Type of samples: Variolitic aphanitic basalts with glass. Samples include lava tube fragments, variolitic pillow fragments, and pillow bud fragments. A few pieces have adhering coral fragments. Character of samples suggests two rock suites: one set from pillow unit and one from flow unit.  
Thin sections show abundant olivine microphenocrysts (5-10%) and a matrix of quenched olivine and some plagioclase microlites. Some samples might be best described as micro-komatiites, with the texture dominated by networks of quenched olivine in groundmass. Appears to be an unusually mafic basalt. Not an andesite as suggested by looking at hand specimens.  
Remarks: Deep-sea sediment.  
Dredged to south over axial high for distance of about 1200m. Dredge site located at north end of rift tip in overlap zone.  
Dredge was on bottom for about 25 min.  
Thin sections made on board ship of some samples, including 35-3, 35-7, & 35-8.  
Rock samples split between Soviet and U.S. scientists.  
Mud and coral fragments to U.S. scientists.

Station number: **ABP-16-36**  
Date: 6 Nov 1990  
Time: 0041z to 0340z  
Sample Site: **MAR - Axial High.** First ridge segment north of Atlantis Fracture Zone.  
Lat/Long: 30°19.39'n, 41°56.60'w to 30°17.46'n, 41°56.08'w  
Water depth: 3784m to 3500m  
Sampling device: Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
Number of samples: 12 rock samples in large dredge. 2 bags of chips & glass in small pipe dredge.  
Type of samples: Fresh basalt with scattered large plagioclase phenocrysts and zenocrysts. Whitish-yellow coatings on joint surfaces (hydrothermal origin?). Thin sections show olivine is common as microphenocrysts and some clinopyroxene. Mineralogically, this suite is relatively "more evolved" than rocks from 16-35.  
Remarks: Dredged to southeast over axial high for distance of about 1800m.  
Dredge was on bottom for about 1 hr and 15 min.  
Thin sections made on board ship of some samples.  
Rock samples split between Soviet and U.S. scientists.

Station number: **ABP-16-37**  
Date: 6 Nov 1990  
Time: 0555z to 0830z  
Sample Site: **MAR - Axial High.** First ridge segment north of Atlantis Fracture Zone. at east end ridge-transform intersection (RTI).  
Lat/Long: 30°07.90'n, 41°56.32'w to 30°05.15'n, 41°55.06'w  
Water depth: 3327m to 3436m  
Sampling device: Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
Number of samples: Mud with a few rock fragments only. 2 small bags each of glass and rock chips.  
Type of samples: Basalt chips and glass and deep-sea sediment.  
Remarks: Dredged to south-southeast over axial high. Moved for distance of about 2000m over bottom with dredge. Dredge was on bottom for about 1 hr. and 10 min.  
Sample only in small pipe dredge.  
Thin sections made onboard ship of sample 37-7(in Houston) and other samples.  
Chips & glass fragments split between Soviet and U.S. scientists.  
Mud to U.S. scientists.

Station number: **ABP-16-38**  
Date: 6 Nov 1990  
Time: 1041z to 1440z  
Sample Site: **Atlantis Fracture Zone.** Inner corner high of first ridge segment north of transform zone. South-facing wall of transform.  
Lat/Long: 30°02.92'n, 42°04.30'w to 30°05.03'n, 42°06.72'w  
Water depth: 3686m to 2520m  
Sampling device: Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
Number of samples: Mud with a few rock fragments only. 2 small bags of rock chips and 10 small pieces of serpentinite gravel.  
Type of samples: Basalt chips and serpentinite gravel in deep-sea sediment.  
Remarks: Dredge dragged in water column to west along scarp and then to north. Moved distance of over 4000m but not sure when dredge was on bottom. Samples could have come from base of scarp as dredge moved westward, or as it was dragged up the south-facing scarp. Sample only in small pipe dredge. One bag of foram sand w/rock chips to Soviet and U.S. scientists. one bag of 10 small serpentinite gravel pieces to Soviets.

Station number: **ABP-16-39**  
Date: 6 Nov 1990  
Time: 1635z to 2000z  
Sample Site: **Atlantis Fracture Zone.** North-facing wall of transform at eastern nodal deep.  
Lat/Long: 29°59.68'n, 42°01.46'w to 29°57.69'n, 42°02.23'w  
Water depth: 3889m to 3150m  
Sampling device: Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
Number of samples: Mud only.  
Type of samples: Deep-sea sediment.  
Remarks: Dredged to south-southwest up steep north-facing scarp. Moved distance of over 2500m but not sure when dredge was on bottom. Samples probably came from base of scarp. Sample only in small pipe dredge. Mud to U.S. scientists.

Station number: **ABP-16-40**  
Date: 6-7 Nov 1990  
Time: 2133z to 0100z  
Sample Site: **Atlantis Fracture Zone.** North-facing wall of transform to west of eastern nodal deep. West of dredge ABP-16-39.  
Lat/Long: 29°59.73'n, 42°08.88'w to 29°58.66'n, 42°09.52'w  
Water depth: 3333m to 2866m  
Sampling device: Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
Number of samples: 1 rock sample and assorted fragments of hyaloclastite & Mn nodules w/mud.  
Type of samples: Basalt with plagioclase and olivine microphenocrysts in cryptocrystalline matrix. Initially thought to be dolerite based on hand specimen, but thin section indicates it is a basalt. Palagonitized glassy rim. Deep-sea carbonate sediment in Mn crust matrix.  
Remarks: Dredged to south-southwest up steep north-facing scarp. Moved distance of over 1000m. dredge was on bottom for about half hour before getting stuck. Freed after about 1 hour and brought up. Sample probably came from depth of about 3000m. Sample split between Soviet and U.S. scientists.

Station number: **ABP-16-41**  
Date: 7 Nov 1990  
Time: 0248z to 0700z  
Sample Site: **Atlantis Fracture Zone.** South-facing wall of inner corner high at east end of transform. Just west of dredge site ABP-16-38.  
Lat/Long: 30°02.37'n, 42°10.28'w to 30°03.18'n, 42°09.41'w  
Water depth: 3919m to 2828m (to 3894m)  
Sampling device: Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
Number of samples: 22 rock samples and two bags of assorted fragments plus mud.  
Type of samples: Peridotites. Partially serpentized with serpentine veins. Many of veins are fibrous with a strong preferred orientation within layers of fibers. Samples have distinctive layer structure caused by alternating zones of peridotite and serpentinite.  
Remarks: All samples look very similar. Probably all from single point on seafloor. Dredged to north up steep south-facing scarp. Moved distance of about 300m. dredge was on bottom for about 20 min. before getting stuck. Freed after about 1 hour and brought up. Samples probably all came from the point where stuck, which was at depth of about 3900-3850m. Thin sections made on board ship of all 22 samples. Samples split between Soviet and U.S. scientists. Mud to U.S. scientists.

Station number: **ABP-16-42**  
Date: 7 Nov 1990  
Time: 0914z to 1840z  
Sample Site: **Atlantis Fracture Zone.** Southeast-facing wall of inner corner high at east end of transform. Just east of dredge sites ABP-16-41 and 16-38.  
Lat/Long: 30°03.36'n, 42°04.50'w to 30°03.04'n, 42°02.95'w  
Water depth: 3635m to 3324m  
Sampling device: Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
Number of samples: Mud only.  
Type of samples: Deep-sea sediment.  
Remarks: Dredge operations delayed 2.5 hrs for winch repairs with 2000m of wire out. Started 2 km west of target site, but drifted almost to site during winch repairs. Dredged to northwest up steep southeast-facing scarp at junction of northern wall of transform and west wall of first ridge segment to north. Moved distance of over 1000m. dredge was on bottom for about half hour before getting stuck. Freed after about one and a half hours and brought up. Sample probably came from depth of about 4000m near base of scarp. Mud to U.S. scientists.

Station number: **ABP-16-43**  
Date: 7 Nov 1990  
Time: 2049z to 2354z  
Sample Site: **Atlantis Fracture Zone.** North-facing wall of central section of transform. Just west of dredge site ABP-16-40.  
Lat/Long: 29°59.07'n, 42°16.29'w to 29°57.55'n, 42°15.46'w  
Water depth: 3641m to 2342m  
Sampling device: Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
Number of samples: Mud only.  
Type of samples: Deep-sea sediment.  
Remarks: Dredged to south up steep north-facing scarp. Moved distance of about 1000m. dredge was on bottom for about 1 hr 20 min. Not sure of sample depth. Probably from base of scarp. Mud to U.S. scientists.

Station number: **ABP-16-44**  
Date: 8 Nov 1990  
Time: 0310z to 0510z  
Sample Site: **Atlantis Fracture Zone.** North-facing wall at west end of transform zone. on the north wall of the western inner corner high.  
Lat/Long: 29°59.32'n, 42°30.96'w to 29°59.79'n, 42°30.43'w  
Water depth: 3345m to 3290m  
Sampling device: Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
Number of samples: 1 fist-sized rock and 6 smaller rock samples. 2 bags of fragments. no mud.  
Type of samples: Ferro-gabbro. Thin sections show variable degrees of shearing, with associated plagioclase deformation and granulation of plagioclase, olivine, and pyroxenes. Sample 44-2 is least deformed and approaches a cumulate igneous texture. There are some large patches of interstitial opaque oxide. Sample 44-4 is almost entirely crypto-crystalline with few olivine phenocrysts possibly a mylonite. It looks like an andesite for dredge 19-45.  
Remarks: Dredged to south up steep north-facing scarp. Moved distance of about 500m. Dredge was on bottom for 30 min. Sample depth probably about 3300m. Rock samples split between Soviet and U.S. scientists.

Station number: **ABP-16-45**  
Date: 8 Nov 1990  
Time: 0800z to 1100z  
Sample Site: **MAR - Axial High.** Ridge-transform intersection at west end of transform zone. axial high to east rift wall.  
Lat/Long: 29°59.21'n, 42°41.65'w to 29°58.44'n, 42°37.80'w  
Water depth: 3145m to 2706m  
Sampling device: Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
Number of samples: 85 rock samples, 4 bags of basalt fragments with glass, and 10 bags of assorted glass/rock samples. Mud sample.  
Type of samples: Basalts, basaltic andesites, and glass. Andesite is the dominant lithology and is characterized by a hackly, gray, vitreous crust and thick variolitic zone. The andesites are almost aphyric. The basalt tends to be plagioclase phyrlic with a thin glassy crust, moderately palagonitized. The andesite has a cryptocrystalline, nearly opaque groundmass, or a matrix of radiating plagioclase microlites in the more crystalline example. There are scattered microphenocrysts of olivine and possibly clinopyroxene. The basalts contain some plagioclase phenocrysts and olivine and plagioclase microphenocrysts and rare pyroxene intergrowths with plagioclase. Thin sections support these inferred petrographic differences.  
Remarks: Dredged to southeast over central volcanic high and then up steep west-facing scarp on east side of rift valley. Moved distance of about 2500m. Dredge was on bottom for about 1 hr 25 min. The two suites of rock samples suggest sampling at 2 different sites: 1 flow unit and 1 pillow unit. Rock samples split between Soviet and U.S. scientists. Mud to U.S. scientists.

Station number: **ABP-16-46**  
Date: 8 Nov 1990  
Time: 1302z to 1600z  
Sample Site: **MAR - Axial High.** First ridge segment south of Atlantis transform zone.  
Lat/Long: 29°50.55'n, 42°47.54'w to 29°50.30'n, 42°47.00'w  
Water depth: 2900m to 2750m  
Sampling device: Large barrel dredge (1 meter x 1.5m) with small tube dredge (0.2m x 0.5m)  
Number of samples: 2 rock samples and 2 bags of glass chips & basalt fragments. No mud sample.  
Type of samples: Basalts and glass. One pillow fragment and one glassy "nose". Scattered plagioclase phenocrysts; matrix is nearly opaque in thin section, but there are a few olivine and plagioclase microlites. Olivine and plagioclase also appear as microphenocrysts.  
Remarks: Dredged to south over central volcanic high. Moved distance of about 1200m. Dredge was on bottom for about 50 min. Rock samples split between Soviet and U.S. scientists.