OCEAN DRILLING PROGRAM

LEG 120 PRELIMINARY REPORT

CENTRAL KERGUELEN PLATEAU

Roland Schlich
Co-Chief Scientist, Leg 120
Institut de Physique du Globe
Laboratoire de Geophysique Marine
5 rue Rene Descartes
67084 Strasbourg Cedex, France

Sherwood W. Wise, Jr.
Co-Chief Scientist, Leg 120
Department of Geology
Florida State University
Tallahassee, Florida 32306

Amanda A. Palmer
Staff Scientist, Leg 120
Ocean Drilling Program
Texas A&M University
College Station, Texas 77840

Philip D. Rabinowitz
Director
ODP/TAMU

Audrey W. Meyer
Manager of Science Operations
ODP/TAMU

Louis E. Garrison
Deputy Director
ODP/TAMU

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SITE SUMMARY
LEG 120

HOLE	LATITUDE	LONGITUDE	WATER DEPTH METERS	NUMBER OF CORES	METERS CORED	METERS RECOVERED	PERCENT RECOVERED	METERS DRILLED	TOTAL PENET.	TIME ON HOLE	TIME ON SITE
747A	54°48.68S	76°47.64E	1705.5	27	256.0	227.1	88.7	---	256.0	42.75	
747B	54°48.68S	76°47.64E	1707.7	6	50.3	48.9	97.2	---	50.3	13.5	
747C	54°48.68S	76°47.64E	1705.0	16	144.5	49.5	34.3	206.0	350.5	82.25	
				49	450.8	325.5	72.2	206.0	656.8		138.5
748A	58°26.45S	78°58.89E	1298.0	2	19.0	19.3	101.3	---	19.0	9.75	
748B	58°26.45S	78°58.89E	1301.4	25	216.3	190.2	87.9	---	216.3	28.0	
748C	58°26.45S	78°58.89E	1301.0	87	760.0	185.9	24.5	175.0	935.0	203.75	
				114	995.3	395.4	39.7	175.0	1170.3		241.5
749A	58°43.03S	76°24.45E	1082.0	1	9.5	10.0	105.7	0	9.5	8.5	
749B	58°43.03S	76°24.45E	1080.0	14	123.8	64.7	52.2	0	123.8	16.75	
749C	58°43.03S	76°24.45E	1080.0	16	147.5	29.9	20.3	102.0	249.5	63.25	
				31	280.8	104.6	37.3	102.0	382.8		88.5
750A	57°35.54S	81°14.42E	2041.0	21	189.3	68.6	36.3	271.2	460.5	103.75	
750B	57°35.52S	81°14.37E	2041.0	5	57.4	24.6	42.9	652.3	709.7	72.0	
				26	246.7	93.2	37.8	923.5	1170.2		175.75
751A	57°43.57S	79°48.83E	1644.3	18	166.2	162.9	98.0	0	166.2		27.5
			TOTALS	**238**	**2139.8**	**1081.6**	**50.5**	**1406.5**	**3546.3**		**671.75**

D I S C L A I M E R

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SCIENTIFIC REPORT

The scientific party aboard JOIDES Resolution for Leg 120 of the Ocean Drilling Program consisted of:

Roland Schlich, Co-Chief Scientist (Institut de Physique du Globe, Laboratoire de Geophysique Marine, 67084 Strasbourg Cedex, France)
Sherwood W. Wise, Jr., Co-Chief Scientist (Department of Geology, Florida State University, Tallahassee, Florida 32306)
Amanda A. Palmer, Staff Scientist (Ocean Drilling Program, Texas A&M University, College Station, Texas 77840)
M.-P. Aubry (Universite Claude Bernard (Lyon I), Departement des Sciences de la Terre, 69622 Villeurbanne, France)
William A. Berggren (Woods Hole Oceanographic Institution, Woods Hole, Massachusetts 02543)
Peter R. Bitschene (Mineralogisches Institut, Ruhr-Universitaet Bochum, Federal Republic of Germany)
Neal A. Blackburn (Britoil PLC, Glasgow, Scotland G25DD)
James Breza (Department of Geology, Florida State University, Tallahassee, Florida 32306)
Millard Coffin (Bureau of Mineral Resources, Geology and Geophysics, Canberra, ACT 2601, Australia)
David M. Harwood (Byrd Polar Research Center, Ohio State University, Columbus, Ohio 43210-1398)
Franz Heider (Geophysics Laboratory, Department of Physics, University of Toronto, Toronto, Ontario, M5S 1A7 Canada)
Mary Anne Holmes (Geology Department, University of Nebraska, Lincoln, Nebraska 68588-0340)
William R. Howard (Department of Geological Sciences, Brown University, Providence, Rhode Island 02912)
Hiroo Inokuchi (Department of Earth Sciences, Faculty of Science, Kobe University, Kobe 657, Japan)
Kerry R. Kelts (Geology Section EAWAG/ETH, CH-8600 Dubendorf-ZH Switzerland)
David Lazarus (Woods Hole Oceanographic Institution, Woods Hole, Massachusetts 02543)
Andreas Mackensen (Alfred Wegener Institute for Polar Research, Columbus-Center, D-2850 Bremerhaven, Federal Republic of Germany)
Toshiaki Maruyama (Department of Earth Sciences, College of General Education, Tohoku University, Kawauchi, Sendai 980 Japan)
Marc Munschy (Institut de Physique du Globe, Laboratoire de Geophysique Marine, 67084 Strasbourg Cedex, France)
Elizabeth Pratson (Borehole Resarch Group, Lamont-Doherty Geological Observatory, Palisades, NY 10964)
Patrick G. Quilty (Antarctic Division, Kingston 7050, Tasmania, Australia)
Frank Rack (Ocean Drilling Program, Texas A&M University, College Station, Texas 77840)
Vincent J.M. Salters (Department of Earth, Atmospheric and Planetary Sciences, 54-1116, MIT, Cambridge, Massachusetts 02139)
James H. Sevigny (Department of Geology and Geophysics, University of Calgary, Calgary, Alberta T2N 1N4, Canada)
Michael Storey (Department of Geology, University of Leicester, Leicester LE1 7RH, United Kingdom)
Atsushi Takemura (Department of Geology and Mineralogy, Faculty of Science, Kyoto University, Kyoto 606, Japan)

David Watkins (Department of Geology, University of Nebraska, Lincoln, Nebraska 68588-0340)
Hubert Whitechurch (Institut de Geologie, 67084 Strasbourg Cedex, France)
James C. Zachos (Graduate School of Oceanography, University of Rhode Island, Narragansett, RI 02882)

ABSTRACT

Leg 120 drilled 12 holes at 5 sites on the Kerguelen Plateau between 54°S and 59°S in the subantarctic Indian Ocean. This leg, along with Leg 119, was planned to study the Late Cretaceous to Holocene paleoceanographic history of the region, the origin and tectonic history of the Kerguelen Plateau, and the nature and age of its basement. Three basement penetrations revealed transitional mid-ocean ridge (T-MORB) type basalt; this is overlain by a mid-Cretaceous(?) non-marine sequence containing weathered volcanics. Upper Cretaceous chalks record subsequent foundering of the Plateau; subsidence continued throughout deposition of the overlying Tertiary pelagic ooze sequence, which also records climatic changes associated with the development of the cryosphere.

INTRODUCTION

Leg 119 and Leg 120 of the Ocean Drilling Program completed a latitudinal transect in the Southern Ocean between Kerguelen Island (49°S) and Prydz Bay, Antarctica (67°S), in order to study the Late Cretaceous to Holocene paleoceanographic history of this region, the origin and tectonic history of the Kerguelen Plateau, the nature and age of the Kerguelen Plateau basement, and the late Mesozoic rifting history of East Antarctica. Leg 119 drilled the Prydz Bay sites and the northernmost and southernmost Kerguelen Plateau sites; Leg 120 drilled the central and southern sites on the Kerguelen Plateau. The two legs were planned to take advantage of the best weather window for the Prydz Bay sites.

Kerguelen Plateau

The Kerguelen Plateau is a broad topographic high located in the south-central Indian Ocean (Fig. 1). It is bounded to the northeast by the Australian-Antarctic Basin, to the south by the 3500 m-deep Princess Elizabeth Trough, to the southwest by the African-Antarctic Basin, and to the northwest by the Crozet Basin. The plateau stretches approximately 2300 km between 46°S and 64°S in a northwest-southeast direction toward the Antarctic continental margin. The feature is between 200 and 600 km wide, and stands 2 to 4 km above the adjacent ocean basins. The Kerguelen Plateau lies south of the present-day Polar Front (Antarctic Convergence) and beneath the main flow of the Antarctic Circumpolar Current. Drilling on the Kerguelen Plateau should therefore document the development and evolution of these two oceanographic features, which have a major effect on global climate and surface-water circulation.

The Kerguelen Plateau has been divided into two distinct domains (Schlich, 1975; Houtz et al., 1977). The northern portion of the plateau, also designated the Kerguelen-Heard Plateau, located between 46°S and 54°S, generally lies in water depths less than 1000 m and includes the feature's only subaerial manifestations: Kerguelen, Heard, and McDonald islands. The southern portion of the plateau, the Southern Kerguelen Plateau, located between 57°S and 64°S, is deeper, generally lying in water depths between 1500 and 2000 m; it shows much more subdued topography. The transition zone exibits a complex bathymetry with a large east-west-trending spur, the Elan Bank, extending westward from the main plateau over a distance of 600 km.

The origin and crustal structure of the Kerguelen Plateau is still a matter of controversy despite geophysical and geological investigations. Three possibilities, each geochemically distinguishable, may explain the feature's origin and crustal nature:

- it is a continental fragment left over from the break-up of India and Antarctica;
- it is a product of excessive on- or off-axis oceanic volcanism, possibly hotspot-related (oceanic island type volcanism);
- it is a thermally or tectonically uplifted oceanic crust (mid-oceanic ridge type volcanism).

None of these possibilities could be eliminated prior to Legs 119 and 120 drilling, and it is still possible that different parts of the feature have different origins (Schlich, 1982; Coffin et al., 1986). Moreover, given the apparent structural complexities, it is also possible that the Kerguelen Plateau has been created by different volcanic processes corresponding to specific tectonic or rifting episodes.

Evolution of the Kerguelen-Heard Plateau

The average sediment thickness in the basin on the Kerguelen-Heard Plateau is about 2000 to 2500 m, with a maximum of 3000 m to the southwest. Munschy and Schlich (1987) identified five seismic units, which are grouped in two megasequences (S and I) separated by a major discordance, A. The upper megasequence, S, is divided into two units (S1 and S2) by the discordance A. The lower megasequence, I, is divided into three units (I1, I2, and I3); units I1 and I2 are separated by a clear reflector, H. Discordance A is a major event in the sedimentary section and marks a hiatus from the middle Eocene to the upper Oligocene-lower Miocene. This event also separates pre-rifting sequences from break-up and post-break-up sequences.

Evolution of the Southern Kerguelen Plateau

The Southern Kerguelen Plateau is characterized by several large basement uplifts and is affected by multiple stages of normal faulting and possibly strike-slip faulting. The most striking feature, the north-south-trending 77°E Graben, delineated by Houtz et al. (1977) in the northwestern part of the southern plateau, extends from 55°S to almost 58°S. To the east the Southern Kerguelen Plateau is delineated by fault scarps of high relief which are flanked by a large abyssal plain, the Labuan Basin (Ramsay et al., 1986). From analysis of the SEASAT-derived free-air gravity field and seismic reflection data, Coffin et al. (1986) concluded that the Southern Kerguelen Plateau may be an amalgamation of disparate structural elements, including broad crustal uplifts, continental fragments, and possible fracture zone ridges and troughs. The central and southern parts of the Southern Kerguelen Plateau are divided into two distinct sedimentary domains, the large Raggatt Basin to the east and an unnamed basin to the west.

Drilling Objectives on the Kerguelen Plateau

Deep-sea drilling to basement on the Kerguelen Plateau, as planned for Ocean Drilling Program Legs 119 and 120, was intended to clarify the origin, nature, and tectonic history of the Kerguelen Plateau to unravel the paleoenvironmental history of this southern region and to test the proposed models of evolution. The major objectives included determination of:

1. The nature and age of the Kerguelen Plateau basement at sites located on identified structural elements. Penetration into basement was planned to be at least 50 m to guarantee recovery of significant rock samples.
2. The nature and age of the different sedimentary sequences.
3. The tectonic history of the Kerguelen Plateau, including the ages of the unconformities, rifting episodes and vertical movements.
4. The paleoceanographic history of the region, including: the latitudinal and vertical variations of water masses, fauna, and flora through time; the shift of the polar front; and the initiation and development of Circumpolar and Antarctic Bottom Water circulation.

To address these questions, the JOIDES Resolution drilled five sites on the central and southern Kerguelen Plateau during Leg 120 (Figs. 1, 2; Table 1). Approximately 1081 m of core was recovered from 12 holes. The cruise comprised 28 operational days and 35 days of transit, between 21 February and 30 April, 1988, beginning and ending in Fremantle, Australia.

DRILLING RESULTS

Site 747

Site 747 (proposed Site SKP-1) lies in the transition zone between the northern and southern Kerguelen Plateau approximately 500 km south of the Polar Front (Antarctic Convergence; 54°48.68'S, 76°47.64'E, 1697.5 m water depth, average of Holes 747A-C). A 296.5-m-thick lower Santonian through upper Pleistocene pelagic sedimentary section and 53.9 m of underlying basalt were cored in three holes using various combinations of APC, XCB, and RCB core barrels. Although located beneath the present-day Antarctic Water Mass, the sediments contain carbonate throughout except for predominantly Maestrichtian volcaniclastic sands, breccias, and cobbles, which denote a major episode of uplift and erosion of the plateau.

Lithologic units are recognized at Site 747 as follows (Fig. 2):

Unit I: (0-32.7 mbsf) upper Pleistocene to Pliocene foraminifer diatom oozes with minor ice-rafted debris and dropstones prevalent only in the upper 20 m, whereas scattered vitric ash layers occur throughout.

Unit II: (32.7-181.45 mbsf) Miocene to lower Paleocene nannofossil ooze and chalk divisible into the following subunits:

- Subunit IIA: Miocene to Oligocene nannofossil ooze (32.7-151.5 mbsf) with scattered vitric ash layers;
- Subunit IIB: Oligocene to Eocene nannofossil chalk (151.5-170.5 mbsf) with hardgrounds near the base (169 mbsf);
- Subunit IIC: Highly bioturbated Eocene to Paleocene nannofossil chalk (170.5-181.45 mbsf), with large (cm-scale) burrows and scattered shallow-water fossils (bivalve fragments, Nummulites?) and a hardground (173.1 mbsf).

Unit III: (181.45-197.20 mbsf) Maestrichtian multicolored volcaniclastic, polygenetic sand, breccia, and cobbles with probable intercalated chalk layers.

Unit IV: (197.20-296.5 mbsf) Maestrichtian nannofossil chalk and thin nodular chert layers.

Unit V: (296.5-350.5 mbsf) basalt flows composed of variably brecciated, veined, and altered aphyric to sparsely phyric basalts.

The sequence documents a succession of tectonic and paleoceanographic events which highlight the geologic evolution of the Kerguelen Plateau. Vesicular basalt flows deposited in a shallow-water to subaerial environment capped the basement structure of the plateau prior to its subsidence and the accumulation of marine sediment, which began at this site by early Santonian time. The oldest sediments recovered are relatively shallow-water glauconitic calcarenites with admixtures of fine volcanic debris eroded from the basement. These are overlain disconformably by deeper water middle Campanian to Maestrichtian chalks with chert stringers and some Inoceramus and pelagic crinoid remains. The succession is interrupted by a series of Maestrichtian debris flows consisting of clay-, sand-, and cobble-sized clastics and breccias eroded subaerially from volcanic basement during what appears to have been a major uplift event that affected much of the plateau. Debris flows include angular clasts of previously lithified Campanian chalk and chert that indicate substantial faulting of the seafloor. The Cretaceous/Tertiary contact is incomplete in that uppermost Maestrichtian to lowermost Danian sediments are missing; volcanic debris is scattered throughout the heavily bioturbated Danian chalks. The remaining Paleocene-lower Oligocene section is highly condensed and is cut by three disconformities where most or all of the upper Paleocene, middle to lower upper Eocene, and a small part of the upper lower Oligocene are missing. Hardgrounds are developed on two of these surfaces. Sedimentation rates for the remainder of the Neogene are remarkably constant at about 5 m/m.y. (Fig. 3), and sedimentation for this interval appears to have been continuous until the late Pleistocene. Although the predominance of biosiliceous ooze throughout the Pliocene-Pleistocene denotes the presence of the Antarctic Water Mass over this site, several species of both planktonic foraminifers and calcareous nannoplankton lived in the surface waters. The top of the section is dated at 0.35 Ma.

The essentially continuous calcareous upper Oligocene to upper Pleistocene record at a site this far south of the present-day Polar Front was unexpected, and this section will serve as an important reference section for an integrated high latitude calcareous and siliceous microfossil biostratigraphy correlated with magnetostratigraphy and lower latitude zonations. A good paleomagnetic polarity record was obtained down to the lower/upper Oligocene contact; virtually all major events (anomaly correlatives) can be recognized as well as most of the polarity chrons. Excellent preservation of planktonic and benthic foraminifers should allow a complementary stable isotope record to be established. Also noteworthy is the pristine preservation of the Danian calcareous microfossils. The Cretaceous planktonic foraminifers and calcareous nannofossil assemblages represent the cool water Austral faunal and Falkland Plateau floral provinces, respectively, except for assemblages present in the lowest Campanian core, which shows a more temperate influence. Campanian-Maestrichtian sedimentation rates were a relatively high 20 m/m.y (Fig. 3).

Based on macroscopic observations, the recovered basement rock consists of approximately 15 separate basalt flows. The separate flows appear compositionally similar and consist of dominantly aphyric, sparsely plagioclase-pyroxene phyric, and olivine-plagioclase phyric basalts. The flows are vesicular, indicating deposition in a shallow-water to subaerial environment. All volcanics exhibit variable degrees of brecciation, veining, and alteration. The alteration minerals consist of zeolites, clays (celadonite and smectites), and calcite fillings in veins, vesicles, and amygdules. Fresh material was recovered from three flows. Trace element chemistry is similar to Transitional Mid-Ocean Ridge Basalt (T-MORB).

The sequence below 90 mbsf was successfully logged despite gale force winds. The resistivity and natural gamma ray logs clearly delimit the major altered and less altered zones in the basement complex (which had been cored with only 38% recovery owing to high seas). The logs also detected basalt breccia debris flows in the lower Maestrichtian which were not cored or only partially cored during drilling.

An approach site survey along a single channel seismic line located the site close to the intersection of two multichannel seismic lines. Correlation with existing seismic data is excellent. A reflector at 0.24 s two-way traveltime (TWT) probably corresponds to lithostratigraphic Unit III, and basement matches a major reflector at 0.35 s TWT. These results agree quite well with the logging data.

Site 748

Site 748 (proposed Site SKP-3C) is located on the Southern Kerguelen Plateau in the western part of the Raggatt Basin, east of Banzare Bank (58°26.45'S, 78°58.89'E, 1290.7 m water depth average of Holes 748B and 748C). The site was intended to recover an expanded section of Paleogene and Cretaceous sediments in order to decipher the tectonic and geologic history of this part of the plateau.

An approach site survey located the site on Rig Seismic MCS line RS02-27 (100.2340). Correlation of the JOIDES Resolution single channel line with existing data is clear and shows at the site two major reflectors which lie at 0.83 and 0.41 s TWT below seafloor. Other reflectors deduced from seismic stratigraphic studies lie at 0.92, 0.61, 0.29, 0.16, and 0.09 s TWT below seafloor.

After coring the upper 215 m of the section with the APC and XCB until refusal, another hole was initiated using the RCB and drilled to 550 mbsf, at which point a model LH minicone was deployed in order to take advantage of a window of relatively calm weather for that operation. The hole was continued to 742 mbsf, whereupon a successful reentry procedure was conducted to change the bit. The hole was then drilled to a total depth of 935 mbsf, where a failed flapper valve allowed massive backflow of sediments into the bottom-hole assembly (BHA), thereby preventing further operations at this site, including logging. Aside from the sediment recovered from the BHA, little material was trapped in cores (i.e., in core-catcher socks) taken over the basal 27 m of the hole, perhaps owing to malfunction of the flapper valve and/or excessive ship heave. Nevertheless, average core recovery over the last 95 m prior to these problems was 70%, and this is the deepest penetration yet achieved via reentry using a minicone. The following lithostratigraphic units were recognized (Fig. 3):

Unit I: (0-15.5 mbsf) Plio/Pleistocene diatom ooze with radiolarian and foraminifer enriched intervals, dropstones, and ice-rafted debris.

Unit II: (15.5-389.1 mbsf) upper Miocene to upper Paleocene nannofossil ooze, chalk, porcellanite, and chert divisible into the following subunits:
- Subunit IIA: (15.5-180.6 mbsf) upper Miocene to middle Eocene nannofossil ooze with biosilica enriched intervals;
- Subunit IIB: (180.6-389.1 mbsf) middle Eocene to upper Paleocene nannofossil ooze, chalk, porcellanite, and chert.

Unit III: (389.1-898.8 mbsf) Maestrichtian to at least upper Campanian glauconitic packstone, wackestone, siltstone, claystone, in part silicified and subdivided as follows:
- Subunit IIIA: (389.1-692.0 mbsf) upper Maestrichtian to upper Campanian glauconitic pack-, grain-, and wackestones, intermittently silicified, with intervals of abundant bryozoans, inoceramid prisms, and crinoid columnals, plus rare red algal debris;
- Subunit IIIB: (692.0-897.6 mbsf) Coniacian(?) to Turonian glauconitic pack-, grain-, and wackestones, compositionally similar to Subunit IIIA but not silicified;
- Subunit IIIC: (897.6-898.8 mbsf)basalt conglomerate with thick-walled bivalve fragments at base.

Unit IV: (898.8-935.0 mbsf) highly altered basalt flow and underlying lithologies, undated but subdivided as follows:
- Subunit IVA: (898.8-902.2 mbsf) sparsely clinopyroxene and plagioclase phyric basalt, strongly weathered and altered;
- Subunit IVB: (902.2-935.0 mbsf) lithologies not encountered above (recovered as fragments in core catcher socks or the BHA), all believed to be derived from basalt weathering: (1) red and green claystone, (2) brown claystone with calcite veins, and (3) highly altered pieces of basalt.

The basalt cored below 898.8 mbsf has compositional characteristics similar to intra-plate, oceanic island alkaline basalts, and may represent the last of a series of basalt flows which, for lack of core recovery, can only be inferred to lie within Subunit IVB. The Unit IV basalts are necessarily younger than those that form the true basement of the Raggatt Basin. These younger flows are strongly weathered, and some appear to be interlayered with siltstones and claystones derived from that weathering; wood fragments, if in place, denote the development of soils and vegetation on some flows. According to regional seismic data, true basement (located at 0.92 s TWT) was not penetrated at this site, but lay some 150-200 m below the total depth of Hole 748C.

Beginning with the basal conglomerate, the first sediments deposited in the basin are glauconitic with up to 0.5% organic matter, denoting a restricted marine environment. No calcareous or siliceous microfossils are preserved; therefore, a determination of the age of these sediments must await shore-based palynological study. Nevertheless, an extrapolation of sedimentation rates from the more fossiliferous strata above suggests a late Campanian age, which is consistent with paleomagnetic data (sediments representing the Cretaceous "quiet zone" were not drilled).

High glauconite contents (up to 20%) characterize the remainder of lithostratigraphic Unit III as do total organic contents of between 0.2 and 0.6% (maximum 1.0%). These are mostly type III hydrocarbons composed of terrestrial and highly oxidized marine organic matter. Datable calcareous microfossils appear at 711 mbsf, and are followed upcore by a host of invertebrates. Some fossils, such as coralline red algae, serpulid worm tubes, and encrusting bryozoans, indicate periods of quiet shallow-water paleodepths (up to inner shelf). The inoceramid remains, which compose up to 80% of some intervals, are exceptionally well preserved, and should provide reliable isotopic paleotemperature data. Some vertebrate teeth recovered belong to sharks and possibly to the giant swimming lizard *Mosasaurus*.

Productivity and consequently sedimentation rates in this shallow, bank-like environment were quite high, some attaining 60 m/m.y. (Fig. 3). Siliceous sponges as well as radiolarians, diatoms, and silicoflagellates contributed abundant biogenic silica that was ultimately responsible for the silicified layers in lithostratigraphic Unit IIIA. The amount of glauconite produced over the entire 500-m-thick Unit III section is extraordinary, particularly in view of the high sedimentation rate.

Mesozoic calcareous nannofossil and planktonic foraminifer assemblages have a strong austral affinity, as at Site 747 to the north. Sedimentation was apparently continuous from the late Campanian into the early Maestrichtian, but the middle Maestrichtian is missing (hiatus = ~5 m.y.). The uppermost Maestrichtian and Danian are also missing (hiatus = ~6 m.y.). This latter gap in the record corresponds to a widespread regional disconformity, noted as the prominent reflector at 0.41 s TWT below the seafloor on our seismic records, and is thought to mark a major tectonic and erosional event that affected much of the plateau (i.e., see Site 747 summary). Subsidence of Site 748 following this erosional event was rapid, probably as a result of extensional tectonics associated with rifting (77°E Graben).

The middle Paleocene through middle Eocene pelagic carbonate and chert sequence is apparently continuous, and was deposited in deeper waters (similar to present day), as subsidence had far outstripped the relatively high sedimentation rate of 20 m/m.y. (Fig. 3). Regional seismic analysis shows that the Paleogene depocenter for the basin had shifted considerably toward the east as a consequence of the profound Maestrichtian tectonic event.

A recovery of 100% in the upper 180 m of the section in Hole 748B provides an excellent Neogene calcareous-biosiliceous section with good paleomagnetic control, which complements that obtained at Site 747. The main elements of the magnetic polarity record from anomaly correlatives 1 to 18 (Pleistocene to late Eocene) have been recognized. Both the upper and lower epoch boundaries of the thick (65-70 m) Oligocene section are clearly defined by bio- and magnetostratigraphy (anomaly correlatives 6C and 13). A striking occurrence of angular quartz sand and micas in the lower Oligocene appears to be ice rafted; if so, this may correspond to early Oligocene glacial events documented in Prydz Bay by ODP Leg 119 drilling. Two minor hiatuses are present in the Oligocene, and parts of the lower and middle Miocene are missing (hiatus = ~5-6 m.y.). A minor late Pliocene hiatus has been detected (2.2 to 3.1 Ma), and the Pleistocene is condensed and discontinuous.

Nevertheless, this site, in conjunction with others cored on the plateau, will be quite valuable for paleoceanographic studies. Taking the Neogene together with the Paleogene and Cretaceous sequences, we have an essentially complete record of the events which highlight the evolution of the Raggatt Basin on the Southern Kerguelen Plateau.

Site 749

Site 749 (proposed Site SKP-4A) is located on the western flank of the Banzare Bank, on the Southern Kerguelen Plateau (58° 43.03'S, 76° 24.45'E, water depth 1069.5 m, average of Holes 749B and 749C). The Banzare Bank corresponds to a smooth basement rise which crests east of the site at a water depth of about 700 m. The sediments gradually thin toward the top of the Bank where several faults cut the basement structure. The site was intended to recover extensive basement rocks from the Southern Kerguelen Plateau with penetration of at least 200 m.

Basement at this site corresponds to a very strong seismic reflector. An approach site survey located the site on Marion Dufresne MCS line MD47-13 (shot point 5670) where the basement reflector lies at about 0.24 s TWT below seafloor. Downslope the sediments thicken in all directions, especially by toplap. Thus the oldest sediment cored at this site does not correspond to the age of basement.

The upper 43.8 m of section was cored with 100% recovery using the APC, whereupon middle Eocene cherts were encountered, which reduced recovery via the APC and XCB to only 26% over the next 80 m. A change to the RCB yielded only 7% recovery through chert, chalk, and ooze to the basement contact at 202 mbsf. After obtaining 5 m of basalt in the next core, the succeeding two cores were essentially empty, and a model LH minicone was deployed to allow the hole to be reentered after a bit change. This was the first use of a free fall minicone for a dedicated basement site.

Inspection of the BHA on deck showed that severe pounding of the bit against hard bottom in high seas at this shallow site had resulted in a badly worn bit and a broken flapper valve. The latter had precluded any recovery in the last two cores. A novel decision was made by the ODP Cruise Operations Superintendent, Mr. Lamar Hayes, to core without a flapper valve, and to institute instead a weighted mud program to prevent backflow of cuttings into the BHA. After a successful (16-min) reentry, this procedure worked beyond expectations, as the next two cores produced 17.83 m of basalt at a recovery rate of 94%. As the last core was being cut, a medical emergency involving Mr. Hayes terminated operations at this site, and JOIDES Resolution was put on course for Fremantle, Australia. Mr. Hayes died on 28 March 1988. The ship arrived at Fremantle on 5 April 1988.

The following lithologic units were recognized at this site (Fig. 2):

Unit I: (0-0.24 mbsf) lower Pleistocene (and upper Pliocene?) diatom ooze with foraminifers and ice-rafted debris; disconformity at base.

Unit II: (0.24-202.0 mbsf) upper Oligocene to lower Eocene nannofossil ooze with chert, chalk, and porcellanite, divisible into the following subunits:
- Subunit IIA: (0.24-43.8 mbsf) upper Oligocene to middle Eocene nannofossil ooze with foraminifers plus some siliceous microfossils and minor volcanic ash in the upper 25 m;
- Subunit IIB: (43.8-202.0 mbsf) middle Eocene to lower Eocene nannofossil ooze, with chalk, chert, and porcellanite; 3% sponge spicules and radiolarians between 53 and 82 mbsf only.

Unit III: (202.0-249.5 mbsf) clinopyroxene, plagioclase phyric basalt.

The 23.1 m of basalt recovered consists of 5 flows and 1 dike. Most flows have altered and vesicular tops but grade to fresh and more massive basalt toward the interior of the flow. The basalts are either quartz or olivine normative tholeiites, and range in Mg# from 46.5 to 57.5. The high Mg# basalt contains olivine and plagioclase (An_{60-80}) phenocrysts. All other basalts have plagioclase (An_{50-60}) as the main phenocryst phase, together with scattered clinopyroxene. The groundmass phases consist of plagioclase (An_{40-50}), clinopyroxene, and Fe-Ti oxides.

These basalts are more depleted in incompatible trace elements than those from the previous Leg 120 sites, although basalts from Holes 747C and 749C have similar Zr/Nb and P/Y ratios. Both Site 747 and 749 basalts are slightly more enriched in incompatible elements than normal Mid-Ocean Ridge Basalt (MORB), and are compositionally similar to transitional basalt (T-MORB). Based on major and trace element chemistry, Site 749 basalts are similar to the Nauru Basin plateau basalts (DSDP Leg 89). In contrast to basalts from Site 747, the basalts from Site 749 do not form a coherent group or trend on key variation diagrams. This indicates that the basalts from Site 749 cannot be related to each other by simple fractional crystallization or partial melting alone.

The alteration occurs in the groundmass, amygdules, veins, and as replacement of plagioclase phenocrysts. The alteration assemblage consists of laumontite (and stilbite), interlayered smectite, calcite, and scattered quartz, which is diagnostic of the high-temperature zeolite facies (100°-$200^{\circ}C$). This alteration assemblage at Site 749 is not observed at normal mid-ocean ridge segments, but does occur in places associated with a high heat flow such as Iceland. The shallow depth of this alteration zone combined with its relative high temperature indicates a high paleo-heat flow.

The oldest sediments above basement are dated at 54 to 55 Ma. Benthic foraminifers indicate that the paleodepth at this site has been virtually constant (between 1000 and 1500 m) since the early Eocene. Sedimentation rates, however, vary considerably, being inferred as high as 70 m/m.y. for the lower and lower middle Eocene, then dropping to a minimum of 7 m/m.y. for the middle middle to upper middle Eocene and 3.6 m/m.y. for the upper Eocene and Oligocene (Fig. 3). The abnormally high sedimentation rate during the early and early middle Eocene may be attributable to constant synsedimentary scouring and redeposition of pelagic oozes, particularly from exposed basement surfaces, thereby contributing to a type of sediment "drift" deposit at this site.

Site 750

Site 750 (proposed Site SKP-3D, (57°35.54'S, 81°14.42'E, water depth 2030.5 m) is located on the southern Kerguelen Plateau in the eastern part of the Raggatt Basin, west of the deep Labuan Basin, approximately 900 km south of the present-day Polar Front. The primary objective was to recover an expanded Cretaceous section reflecting the early tectonic and depositional history of the Southern Kerguelen Plateau. A second objective was to obtain, if feasible, basement samples from the Raggatt Basin in a zone of dipping reflectors.

Beginning with this site on 14 April 1988, JOIDES Resolution resumed operations on the Southern Kerguelen Plateau following the unscheduled port call to Fremantle, Australia, requiring a transit of 17 days and 4400 nmi. The site was approved during the transit as a substitute for proposed Site SKP-3B, and is located 18 km to the east on the same seismic line. The basement reflector at Site 750 lies at about 0.69 s TWT below the seafloor and three major seismic reflectors can be traced at 0.59, 0.46, and 0.31 s TWT.

Hole 750A was wash- and interval-cored using a rotary bit through middle and lower Eocene ooze, chalk, and chert to 297.5 mbsf; below 143 mbsf the combination of cherts and heavy seas had their usual deleterious effect on core recovery, which was only 3% for the 3 rotary cores taken. After a 24-hr weather delay, continuous coring through Paleocene-Maestrichtian chalk to 423.3 mbsf yielded a nearly complete but drilling-disturbed K/T boundary sequence at 348 mbsf; recovery was 47%. The hole was terminated at 460.5 mbsf by total bit failure (disintegration) after only 5-1/2 hr of rotation, whereupon a successful logging run was made using a combination of seismic stratigraphy tools; a second run in rough seas using lithodensity tools was foiled by damage to the cable head. Operations were suspended on 18 April with hopes of reoccupying the site following drilling at Site 751 (proposed Site SKP-2C) located 46 nmi. to the west.

As it developed, the site was reoccupied on 20 April, and Hole 750B was washed using the RCB to 450 mbsf, taking only one wash core on the way. After pulling a second wash barrel, the hole was continued with rotary or wash cores taken every 10 to 30 m through cherty Cretaceous chalk and limestone with the intention of maintaining a rate of progress of at least 10 m/hr. This rate was deemed necessary to reach basement before drilling time for the leg expired if the single bit were to survive to the projected total depth. Drilling with a hard formation bit slowed considerably when the formation changed from marine limestone to terrestrial clay below 624 mbsf; however, a velocity inversion at that point decreased considerably the predicted depth to basement, which was encountered at 675.5 mbsf.

Thereafter a series of thick basalt flows was drilled with 67% recovery to a total depth of 709.7 mbsf.

The following lithologic units were recognized (Fig. 2):

Unit I: (0-0.37 mbsf) Plio-Pleistocene diatom ooze and lag deposit. Repeated within the first core by a double punch of the drill string, this unit contains diatoms and foraminifers of early Pleistocene and mid-Pliocene age. The lag contains sand and ice-rafted pebbles with heavy manganese coatings; a disconformity occurs at the base.

Unit II: (0.37-357 mbsf) middle Eocene to Paleocene nannofossil ooze, chalk, and chert, divisible into the following subunits:

Subunit IIA: (0.37-317.2 mbsf) middle Eocene to Paleocene white nannofossil ooze, chalk and chert;

Subunit IIB: (317.2-357 mbsf) Paleocene white nannofossil chalk. Cross-cutting gray solution seams are evident below 317 mbsf. Just above the K/T contact, the white chalk darkens downward to an olive-gray color; dark specks are present and there is an concomitant increase in magnetic susceptibility. Lowermost Danian nannofossil Zone NP1 is present but contains reworked Cretaceous material. The K/T contact, which was disturbed by drilling, marks an abrupt change in lithology from well-consolidated Danian chalk to soft Maestrichtian ooze of the nannofossil Nephrolithus frequens Zone. The more clay-rich lower Danian section appears to show up as a positive excursion on the resistivity logs, which may allow a more precise placement of the base of this subunit.

Unit III: (357-623.5 mbsf) Maestrichtian to Turonian (Cenomanian?) nannofossil chalk, chert, and intermittently silicified limestone, subdivided as follows:

Subunit IIIA: (357-450 mbsf) Maestrichtian to upper Campanian nannofossil chalk and minor chert. Solution seams characterize this subunit along with burrows, laminae, and rare stylolites. Some pale purple laminae may represent redox changes; three gray laminae contained 50% zeolite. Microfossils are exceptionally well preserved in the upper Maestrichtian; echinoid spines are a persistent component and a brachiopod shell was found at 385 mbsf.

Subunit IIIB: (450-594.6 mbsf) upper Campanian intermittently silicified limestone and calcareous chalk, poorly recovered; bioclast fragments include small molluscs, crinoid columnals, and inoceramids.

Subunit IIIC: (594.6-623.5 mbsf) mixed Cenomanian and Turonian (and Campanian?) chalk with dark clayey interlayers. Cenomanian microfossils may be reworked; the darker clays may be redeposited. Pyritized wood fragments, a bivalve, and traces of glauconite are also present.

Unit IV: (623.5-675.5 mbsf) undated red to dark gray-brown silty claystone with charcoal and minor conglomerate. This unit consists of a broad range of water-laid terrigenous claystones and siltstones, with some sandy or conglomeratic intervals. Carbonized wood fragments from land plants are abundant, as are coarse, authigeneic siderite and pyite grains and concretions. Where first sampled, this unit consists of a massive, plastic reddish brown, silty claystone composed primarily of kaolinite, but with up to 25% siderite (as coarse authigenic grains), 20% opaques, 6% pyrite, and 20% altered grains that may be derived from basalt. The next core yielded a much darker, grayish brown clayey siltstone, which is more fissile and richer in organic matter (up to 7%). A highly colorful, 25-cm-thick soft pebble conglomerate and sand displays grading, cross-stratification and small scale current bedding. Incorporated among the rounded to subrounded, 0.5-3 mm silt- and claystone ferruginous grains are numerous large (cm-scale) pieces of carbonized wood. Wood fragments are also enclosed within siderite cemented claystones and a siderite concretion at the base of the unit.

Unit V: (675.5-709.7 mbsf) basalt flows composed of moderately to highly altered plagioclase-clinopyroxene phyric basalt. At least four flows were recovered, of which the third flow represents the majority of the recovery, being a 11.5-m massive basalt flow. The lower two flows are separated by a chilled margin and are overlain by highly altered volcanics. The flows are restricted in composition to olivine-hypersthene normative tholeiites. The secondary mineral assemblage consists of smectite and calcite with minor quartz and scattered zeolite (chabazite).

The three major seismic reflectors observed at Site 750 above basement at 0.31, 0.46, and 0.59 s TWT are related to major changes in the lithology, physical properties, and logging data. The reflector at 0.31 s can be correlated with the boundary between Subunits IIA and IIB (317.2 mbsf). The seismic reflectors at 0.46 and 0.59 s TWT must be correlated with the top of Subunit IIIB (450 mbsf) and the top of Subunit IIIC (594.6 mbsf), respectively. On the basis of these correlations the calculated mean velocities for each lithologic unit or subunit are in good agreement with the measured compressional wave velocities. A clear but unusual velocity inversion is observed between 600 mbsf and the top of the basalt unit at 675.5 mbsf. A similar inversion was recorded at Site 748 in the western Raggatt Basin.

Both the basement and the sedimentary rocks drilled at this site provide interesting contrasts with those sampled elsewhere on the Kerguelen Plateau during this leg. In terms of incompatible trace element abundances, basalts from Site 750 are the most depleted, thereby extending the array defined by samples from Sites 747 and 749. They also show slight differences in incompatible element ratios, possibly indicating differences in source characteristics. Nevertheless, Site 750 basement is transitional in characteristics between normal Indian Ocean MORB and Kerguelen Island and Heard Island OIB lavas. The secondary mineral assemblage at this site indicates low-temperature alteration (<50°C), as opposed to the higher temperature regimes defined at Sites 747 and 749. The alteration occurred under oxidizing conditions, and the basalts were erupted in a subaerial or shallow subaqueous environment.

Following the emplacement of the uppermost basalts at this site, a considerable part of the southern Kerguelen volcanic edifice was emergent and subject to intense weathering in a warm temperate or subtropical climate (in marked contrast to that in this region today). Rainfall was sufficient to weather volcanics to kaolinitic clays. The actual source rock may not have been entirely the T-MORB basalts drilled at this site, but rather alkaline basalts located elsewhere in the rather extensive watershed (perhaps similar in composition to those drilled at Site 748). The kaolinites accumulated in well-vegetated or forested, subaqueous or subaerial environments, perhaps on marshy flood plains. The soft pebble conglomerate probably denotes fluvial conditions, and the authigenic siderite crystals are characteristic of coal swamps. The numerous large pieces of charcoal (up to 5 cm) and high organic carbon contents of up to 7% further suggest a terrestrial setting. These sediments are visually similar to but mineralogically different from those penetrated but poorly sampled in lithologic Unit IV at Site 748.

Foundering of this part of the Kerguelen platform occurred by Cenomanian time. The oldest recovered chalks contain evidence of redeposition of inner shelf faunas into a deeper water environment. By the late Campanian, the subsidence had carried the site to upper slope depths; sedimentation rates increased considerably and surface temperatures cooled, so that planktonic foraminiferal assemblages changed from transitional to austral in character. Only in the late Maestrichtian did the foraminifer and nannofossil assemblages lose their strong austral affinities, apparently indicating a progressive warming leading up to the close of the Cretaceous Period. By then the site had deepened to perhaps bathyal depths. Conditions at this site during the deposition of these Upper Cretaceous chalks were consistently open marine, in strong contrast to the restricted Turonian-Coniacian glauconitic siltstones and shallow water glauconitic bioclastics that characterized the western Raggatt Basin (Site 748). Nor is there evidence of the Maestrichtian-lower Danian debris flows encountered at Site 747 to the north. The western Raggatt basin stood structurally higher than the eastern part of the basin throughout the Late Cretaceous, subsiding rapidly only at the end of the Maestrichtian, and Site 748 remains 740 m shallower than Site 750 today. These different histories are well reflected in our sedimentological and seismic stratigraphic records.

Surprisingly high sedimentation rates of 11 m/m.y. characterize the Danian, which spans 40 m of section at Site 750 (Fig. 3). Danian benthic foraminiferal faunas are similar to those of the upper Maestrichtian; by then, the paleodepth of the site was approaching that of the present day. Sedimentation rates increased to about 30 m/m.y. during the late early and late middle Eocene. Except for the thin Plio-Pleistocene veneer and lag deposit, the rest of the Cenozoic record is missing at this site.

Basalts from Site 750 are more depleted in incompatible trace elements than any of the other basalts recovered on Leg 120. This may indicate that basalts from Hole 750B were produced by higher degrees of melting than those of Sites 747 and 749. Excluding the single OIB basalt flow drilled at Site 748, Leg 120 basalts show some inter-site variation in incompatible element ratios, possibly indicating source heterogeneities. However, these differences are minor relative to the large chemical variability exhibited by basalts erupted at ocean ridges and intra-plate islands. Basalts from Sites 747, 749, and 750 are transitional in character between normal Indian Ocean MORB (Price et al., 1986) and Kerguelen and Heard island OIB lavas (unpub. data, Storey). Compositionally, they show affinities with Nauru

Basin basalts (Saunders, 1985), transitional basalts from the South West Indian Ridge (le Roex et al., 1983), and the oldest basalts from Kerguelen Island (unpub. data, Storey). The alkaline basalt lava from Hole 748 is quite distinctive, being extremely enriched in incompatible elements with compositional characteristics typical of OIB-type magmatism.

Site 751

Site 751 (proposed Site SKP-2C) is located in the central part of the Raggatt Basin on the Southern Kerguelen Plateau (57°43.57'S, 79°48.83'E, water depth 1633.8 m), and was intended to recover a high-resolution Neogene and Paleogene stratigraphic section deposited above the calcium carbonate compensation depth and well south of the present day Polar Front, which lies 900 km to the north. This site is a key component of a latitudinal paleoceanographic transect across the plateau. The Marion Dufresne MCS line MD47-05 shows a thick sedimentary cover of at least 2500 m at this locality. Owing to time constraints imposed by the mid-cruise round trip between the Kerguelen Plateau and Fremantle, Australia, drilling at Site 751 was limited to the Neogene objective, which comprises a seismic sequence of 0.24 s TWT.

A 166.2-m section of upper Pleistocene through middle lower Miocene mixed biosiliceous and calcareous ooze was cored using the APC with 98% recovery. An unusual finding was an exceptionally young (early Pliocene age) porcellanite bed encountered in Core 120-751A-2H. Operations in high seas were terminated when the APC piston rod failed during pullout, leaving the core barrel and the last core stuck in the hole. The following lithologic units are recognized at this site (Fig. 2):

Unit I: (0-40.1 mbsf) upper Pleistocene (>0.2 Ma) to lower Pliocene diatom ooze with minor ice-rafted debris, foraminifers, volcanic ash and porcellanite. The carbonate content ranges from 0 to 70% whereas foraminifers range from ~3% to 25% near the top to rare near the bottom of the unit. Ice-rafted debris is scattered in minor abundance throughout the unit, mostly as sand-sized specks. The predominantly milky white porcellanite, disturbed by drilling, fills the top 44 cm of Core 120-751A-3H and contains some burrow-like casts. Two vitric ash layers are present in the lower Pliocene sediments.

Unit II: (40.1-166.2 mbsf) upper Miocene to lower Miocene diatom nannofossil ooze. Although nannofossils predominate, diatoms occur in equal or greater abundance in many intervals; foraminifers, radiolarians, and silicoflagellates are rare or in trace amounts. Faint green cm-scale laminae enriched in diatoms occur between 88 and 104 mbsf.

The lower Pliocene through lower Miocene represents an expanded section with sedimentation rates of 15 to 20 m/m.y., whereas much lower rates of about 3 m/m.y. characterize the abbreviated upper Pliocene-Pleistocene section (Fig. 3). As many as four hiatuses have been detected. The most extensive of these can be correlated across the Raggatt Basin and spans the interval from about 12.5 to 16 Ma in the middle Miocene. A second represents about 3.5 m.y. between 9.5 and 6 Ma in the late Miocene. A third short hiatus represents about 0.4 m.y. between 4.8 and 5.2 Ma, whereas a fourth spans an interval of some 0.3 m.y. between 1.9 and 2.2 Ma in the late Pliocene. Magnetostratigraphic data are of mixed quality, but key polarity reversals are identified for the early Pliocene to late Miocene (anomaly correlatives 3, 3A, 4, and 5) and early Miocene (anomaly correlatives 5C through 6).

High biogenic silica contents in lithologic Unit I yielded low bulk densities and high porosity values relative to Unit II. Compressional wave velocity values, however, were generally higher above 45 mbsf than below this level in the nannofossil ooze (1560 m/s above vs. 1505 m/s below). The corresponding seismic data do not indicate a correlation of lithologic subdivisions or identified hiatuses with specific reflectors. From the compressional wave velocity measurements, however, it is anticipated that the first reflector at 0.24 s TWT lies just below the bottom of the hole at about 185 m and may correspond to the Oligocene/Miocene contact. If so, sedimentation rates would suggest that a disconformity could be expected at this point.

The relatively high carbonate contents and high sedimentation rates for the Miocene at this site, plus the co-occurrence of siliceous and calcareous microfossil groups, are unique for these high southern latitudes and will make this and other Leg 120 sites on the Kerguelen Plateau important reference sections for stable isotope and biomagnetostratigraphic studies. Changing microfossil assemblage compositions within each group indicate repeated fluctuations of major water mass properties over the site and should provide important paleobiogeographic and paleoceanographic records for this region. The most striking feature of this record is the rapid meter-scale alternations in microfossil assemblage characteristics, physical and sedimentological properties which indicate that this site may have been capturing some of the high-frequency paleoclimatic variability observed in other parts of the world ocean.

CONCLUSIONS

The evolution of the Southern Kerguelen Plateau as derived from drilling results and deduced from seismic stratigraphic analyses can be summarized as follows:

1. The Southern Kerguelen Plateau basalts were erupted prior to the Cenomanian under subaerial or shallow depth conditions and were emplaced on a near-horizontal surface. The basalt flows are relatively thick and massive in the eastern part of the Raggatt Basin (Site 750), fresh to highly altered on the Banzare Bank (Site 749), and strongly weathered and interlayered with siltstones and claystones derived from that weathering in the western part of the Raggatt Basin (Site 748). The early sedimentation denotes fluvial conditions and consists at Site 750 of a broad range of water-laid terrigenous claystones and siltstones, with some sandy or conglomeratic intervals. These sediments are visually similar to those penetrated but poorly sampled at Site 748. Wood fragments, if in place, denote the development of soils and vegetation on some of these flows.

2. During the Cenomanian, Turonian, and probably Santonian, sedimentation evolved in the eastern part of the Raggatt Basin (Site 750) to open marine deposits consisting of chalk with dark clayey interlayers.

During this time span the eastern margin of the plateau slowly subsided to a depth of about 50 m below sea level. To the west (Site 748) the plateau remained almost subaerial or at very shallow depths, and the sedimentation still consists of glauconitic sand-, silt-, and claystones, with no or rare silicified bioclastic debris and some pyritized wood fragments.

3. During the Campanian and late Maestricthian the eastern margin of the Southern Kerguelen Plateau subsided rapidly to a depth of about 2000 mbsf and open marine sedimentation continued with nannofossil chalk, chert, and intermittently silicified limestone; the corresponding sedimentation rate is estimated to be 10-20 m/m.y. To the west the plateau subsided only slowly and remained at shallow depth (50-200 m) throughout this period of time. The sediments consist of glauconitic sandstones, siltstones, and claystones, evolving progressively to intermittently silicified rudstones, grainstones, and wackestones; the sedimentation was almost continuous with a rate of about 46 m/m.y.

4. At about 75 Ma a major tectonic episode affected the eastern margin of the Southern Kerguelen Plateau (Site 750). To the west this tectonic event was recorded at about 68 Ma (Site 748). Normal listric faults developed to the east (Site 750) and are possibly related to the breakup between the Southern Kerguelen Plateau and Broken Ridge-Diamantina Fracture Zone. To the west (Site 748) this event corresponds to the emplacement of the 77°E Graben and to a large northwest-southeast uplift which abuts the southern end of the 77°E Graben. At this time the western margin of the Raggatt Basin (Site 748) subsided rapidly from 50-200 m to 1000 m, at a rate of about 150 m/m.y.

5. From the late Maestrichtian to the middle Eocene, sedimentation mainly nannofossil chalk and ooze with some occurrence of chert, was essentially continuous all over the plateau at a rate of about 18 m/m.y. to the west (Site 748) and at a rate varying between 5 and 30 m/m.y. to the east. During this period of time the plateau subsided slowly and remained at about the same depth.

6. A hiatus of at least 2 m.y. occurred during the middle Eocene (Sites 748 and 750). At Site 747, in the transition zone between the northern and southern Kerguelen plateaus, this hiatus extends over 15 m.y. and is accompanied by a subsidence of about 500 m (30 m/m.y.). This event can be related to the separation by seafloor spreading of the Northern Kerguelen Plateau and Broken Ridge, dated at 43-42 Ma (Munschy and Schlich, 1987).

7. From the middle Eocene to the Pliocene, sedimentation continued all over the plateau and consisted mainly of nannofossil ooze. The sedimentation rate in the central part of the plateau was very high and varied between 15 and 20 m/m.y.

8. During the Pliocene and Pleistocene a low sedimentation rate of 3 m/m.y. is recorded in the central part of the Raggatt Basin (Site 751) and is related to the main erosional event, which affects the whole Southern Kerguelen Plateau.

Leg 120 deep-sea drilling clearly established the basaltic nature of the Southern Kerguelen Plateau basement rocks and greatly contributed to deciphering the Cretaceous tectonic and evolutionary history of one of the world's largest submarine plateaus.

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TABLE 1. LEG 120 SITE SUMMARY

HOLE	LATITUDE	LONGITUDE	WATER DEPTH (m)*	NUMBER OF CORES	METERS CORED	METERS RECOV'D	PERCENT RECOV'D	METERS TOTAL PENET.
747A	54°48.68'S	76°47.64'E	1695.0	27	256.0	227.1	88.7	256.0
747B	54°48.68'S	76°47.64'E	1697.2	6	50.3	48.9	97.2	50.3
747C	54°48.68'S	76°47.64'E	1694.5	16	144.5	49.5	34.3	350.5
748A	58°26.45'S	78°58.89'E	1287.5	2	19.0	19.3	101.3	19.0
748B	58°26.45'S	78°58.89'E	1290.9	25	216.3	190.2	87.9	216.3
748C	58°26.45'S	78°58.89'E	1290.5	87	760.0	185.9	24.5	935.0
749A	58°43.03'S	76°24.45'E	1071.8	1	9.5	10.0	105.7	9.5
749B	58°43.03'S	76°24.45'E	1069.5	14	123.8	64.7	52.2	123.8
749C	58°43.03'S	76°24.45'E	1069.5	16	147.5	29.9	20.3	249.5
750A	57°35.54'S	81°14.42'E	2030.5	21	189.3	68.6	36.3	460.5
750B	57°35.52'S	81°14.37'E	2030.5	5**	57.4	24.6	42.9	709.7
751A	57°43.57'S	79°48.83'E	1633.8	18	166.2	162.9	98.0	166.2

*Water depths are drillpipe depths corrected for the distance between the rig floor and sea level (10.5 m).

**Twelve "wash cores" were taken also.

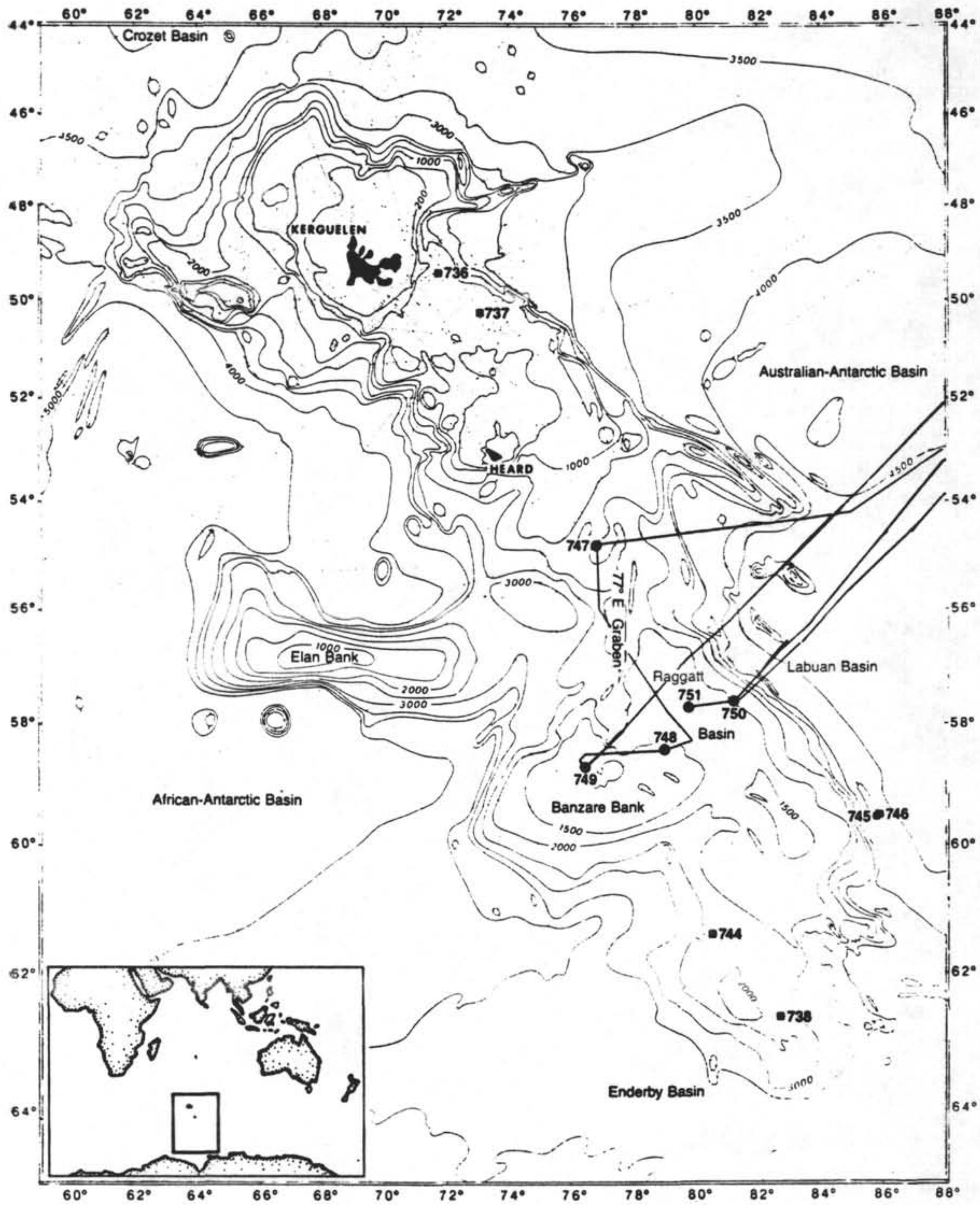


Figure 1. Bathymetric chart of the Kerguelen Plateau after Schlich et al. (1987). The contour interval is 500 m. Locations of Leg 120 (and Leg 119) drill sites are indicated.

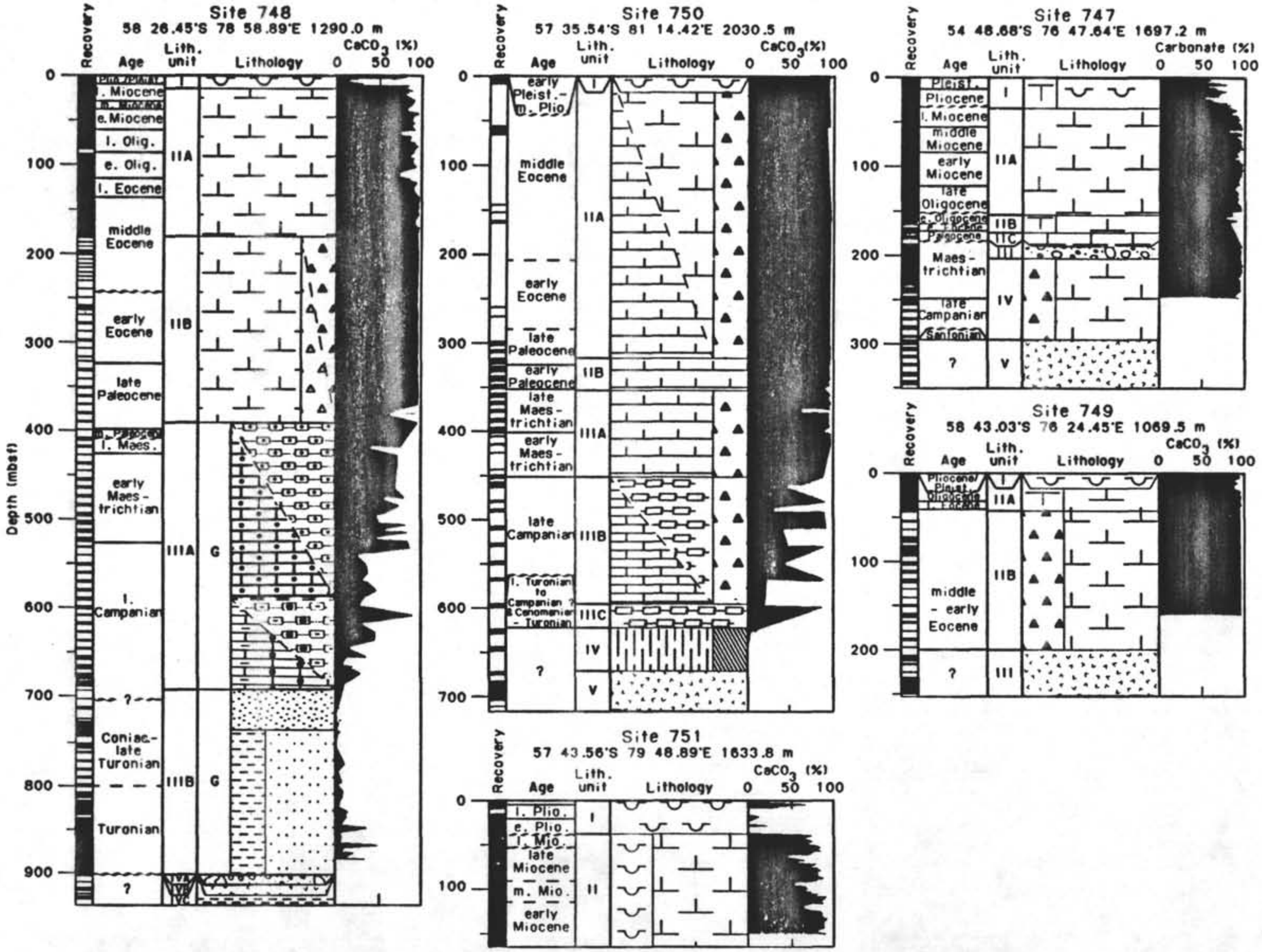
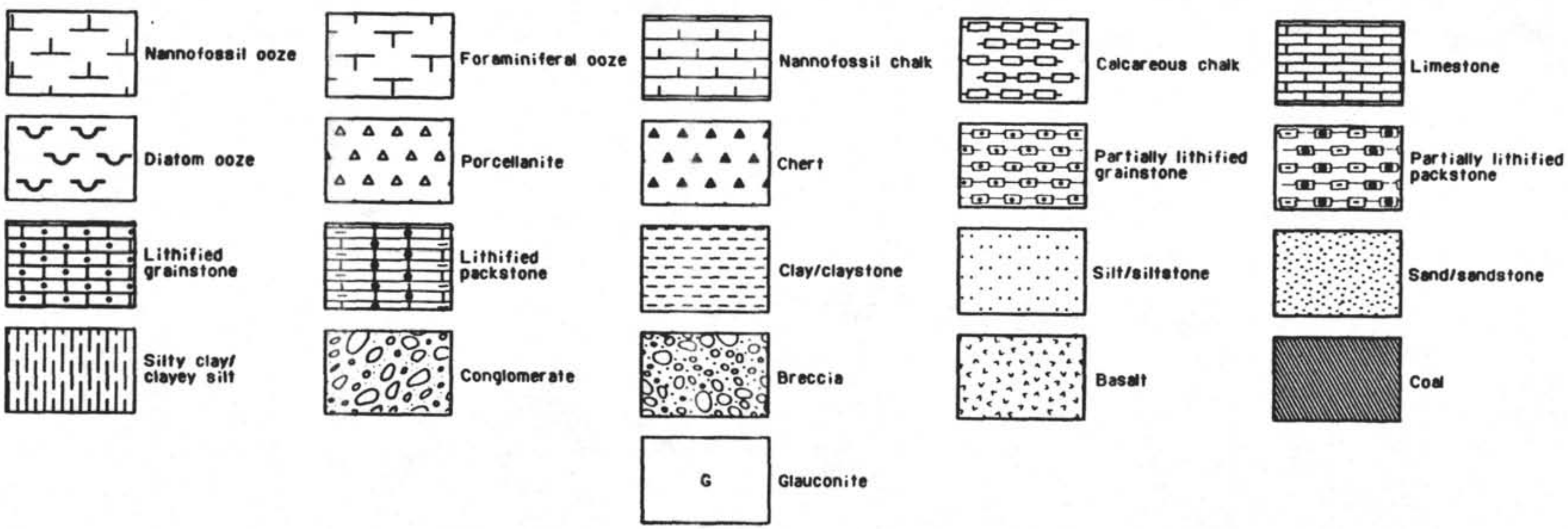


Figure 2. Stratigraphic column for Leg 120 drill sites showing recovery, ages, lithogical units, lithologies, and percentages of calcium carbonate. See key for lithologic symbols.

Key for Figure 2. Lithologic symbols.



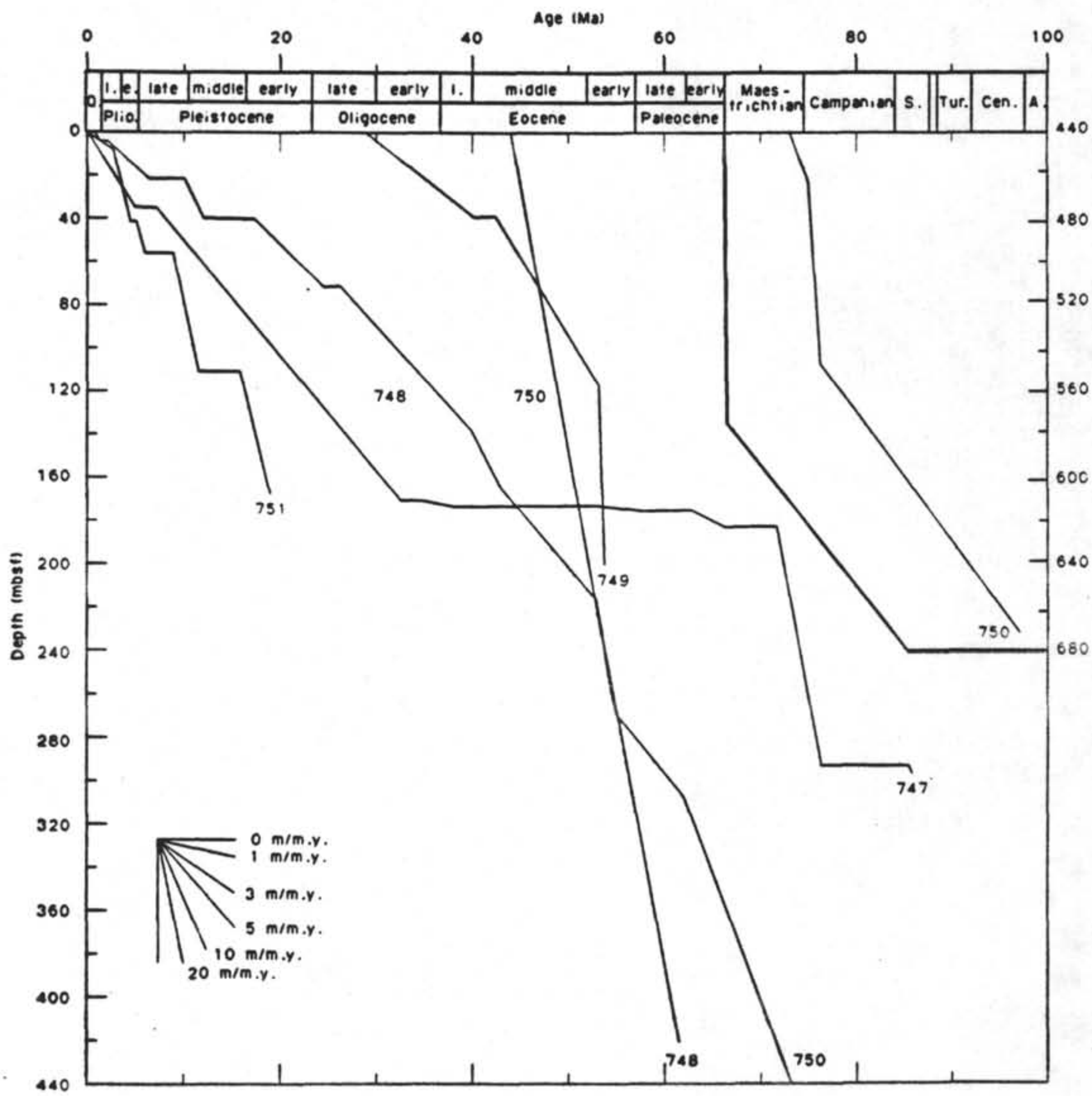


Figure 3. Composite sedimentation rate plot for Leg 120 drill sites.

OPERATIONS SYNOPSIS

The ODP Operations and Engineering Personnel aboard JOIDES Resolution for Leg 120 were:

Operations Superintendent	Lamar Hayes
Operations Superintendent	Glen Foss

OPERATIONS SYNOPSIS

INTRODUCTION

Leg 120 began at 0715 hr, 21 February 1988 in the port of Fremantle, Western Australia, and ended in Fremantle when the first line was cast at 0915 hr, 30 April 1988. The expedition was interrupted by tragedy, the death of Operations Superintendent Lamar Hayes. Because of the time lost in the compassionate repatriation voyage to Fremantle, a 4-day extension was granted to aid in completion of the scientific objectives.

Operating in the southern high latitudes in the months of March and April was a challenge. High winds and heavy seas (Figs. 1 and 2) while operating at relatively shallow water depths were a constant concern. During this 69-day leg, 12 holes were cored at 5 sites. Total core recovered was 2139.8 m, with a recovery rate of 50.5%. The vessel spent 35 days under way, 28 days on site and 6 days in port. Weather conditions caused delays totaling 1.8 days, and 1.4 days (including port and site time) were lost to equipment downtime.

FREMANTLE PORT CALL

A total of 1761 metric tons of fuel, 894 short tons of drill water and oncoming surface and air freight were loaded aboard JOIDES Resolution. Other port call activities were load testing of the ship's cranes to American Bureau of Shipping specifications; Leg 119 bottom-hole assemblies inspection by magnaflux; installation of a new field coil in the P116B propulsion motor; and installation of a new Racal-Decca plotting radar on the bridge.

The MARISAT receiver became inoperative the day the ship arrived in Fremantle. The necessary repair parts had to be hand-carried from the United States, causing the scheduled 5-day port call to be extended by 16 hr. With MARISAT repairs complete, the vessel departed Fremantle at 2345 hr, 26 February.

FREMANTLE TO SITE 747 (SKP-1)

The transit to the Kerguelen Plateau operating area required 9 days. Winds to 40 kt and heavy seas reduced vessel speed to 7 kt after the 6th day, but conditions improved in time for the beacon drop at 2230 hr, 6 March.

SITE 747 (SKP-1); CENTRAL KERGUELEN PLATEAU

Hole 747A

The seafloor was established at 1705.5 m (all depths in this synopsis were measured from the rig floor, not from sea level) with the first APC core. A total of 16 APC cores were recovered before the pullout force reached 60,000 lb. Recovery was 100%. Coring was advanced with the XCB coring system, and chert stringers were found interbedded in soft chalk. The abrasive chert wore the teeth off the XCB cutting shoes while Cores 120-747A-19X to 120-747A-27X were cut to total depth at 256 mbsf.

The hole was displaced with weighted mud, the drill string was pulled above the mud line at 1730 hr, 8 March, and the bit was positioned to shoot the mud line for Hole 747B.

Hole 747B

The APC was deployed six times to 1758 m (50.3 mbsf). One heat flow measurement was taken after the last core. With the coring objectives met, the drill string was tripped out at 0645 hr, 9 March, and the ship was offset 40 m west of Hole 747B.

Hole 747C

The bottom stand of drill collars was replaced with a rotary coring 9-drill-collar assembly, and a mechanical bit release was added to the BHA. After a 1-hr wait for the automatic station-keeping (ASK) system to stabilize in adverse weather, the hole was spudded and drilled/washed from 1705 to 1864 m (0-159 mbsf). The rotary core barrel (RCB) was deployed, and five cores were retrieved. The center bit was again deployed to continue drilling/washing to the next core point at 1957 m (202 mbsf).

The hole was cored from 1957 to 2000 m (202-295 mbsf) with very poor recovery in chalk with chert stringers. Recovery improved somewhat with depth, and basalt was cored at about 297 mbsf. The scientific target was considered to have been reached when 54 m of basalt had been cored.

A wiper trip was made up to 100 mbsf and back to total depth. The mechanical bit release (MBR) was successfully released, the hole was displaced with polymer mud, and the pipe was pulled to logging depth.

One successful logging run, the seismic stratigraphy combination, was made. Further logging attempts were canceled owing to deteriorating weather, and the drill string was recovered after 9-1/2 hr waiting on weather (WOW) time.

SITE 748 (SKP-3C); WESTERN FLANK, RAGGATT BASIN

Hole 748A

An XCB bit and BHA were run to the seafloor, and the bit was positioned at 1300 m to shoot the mud line at 1304 m (PDR). Almost a full core barrel was recovered on Core 120-748A-1H, and some doubt remained about the seafloor depth. After Core 120-748A-2H had been retrieved, the bit was pulled clear of the seafloor to respud and establish the correct depth.

Hole 748B

The bit was positioned at 1292 m, and the interface was recovered by the next APC core from 1301.4 m. Continuous APC coring then proceeded in nannofossil ooze and chalk to 181 mbsf, where overpull reached 50,000 lb. Core recovery was 100%. Temperature probe runs were made after Cores 120-748B-10H and 120-748B-15H were cut.

XCB coring then continued in chalk with chert stringers to 216 mbsf, with an average core recovery of only 15%. When the chert began to destroy XCB shoes, further XCB penetration was abandoned in favor of the RCB system. The hole was filled with weighted mud, and the drill string was tripped for a RCB bit and BHA.

Hole 748C

After a jet-in test to determine casing point for the planned reentry cone, Hole 748C was spudded at 1615 hr, 15 March. The hole was drilled to 172 mbsf, and a temperature probe measurement was taken before continuous RCB coring commenced.

Core recovery started out no better than with the XCB and soon became worse. Only hard siliceous streaks were recovered, and the soft chalk interbeds were lost. Recovery was further hampered by deteriorating weather conditions as winds gusted to 50 kt and vessel heave reached 8 ft.

With more severe weather forecast, operations were interrupted at 531 mbsf for the deployment of a free-fall reentry funnel (FFF or minicone). The funnel was emplaced to provide the option of deepening the hole in case weather forced a hasty withdrawal.

Core recovery improved somewhat with depth and, at 742 mbsf, the pipe was tripped for a new bit in hopes of achieving the site objectives in Hole 748C. Reentry was accomplished after 1-1/2 hr of scanning, and the bit was run to total depth with difficulty owing to deteriorating hole conditions.

At 798 mbsf, operations were interrupted for a day by a ground fault in the top drive power cable. Coring then continued with recovery improving but hole conditions worsening. Basalt was reached at about 900 mbsf. After an additional 35 m, coring operations were terminated owing to unstable hole conditions. During attempts to condition the hole for logging, the BHA became plugged by a float valve flapper failure. The hole was abandoned at that point because a pipe trip was required.

SITE 749 (SKP-4A); WESTERN BANZARE BANK

Hole 749A

The bit and BHA that had been used for Holes 748A and 748B were again employed for the APC/XCB work at Site 749. For the initial core, the bit was positioned a full 5 m above the PDR depth of 1087.3 m. Again the core barrel was recovered full of sediment, and it was necessary to respud to ascertain that the seafloor was cored.

Hole 749B

The subsequent attempt established seafloor depth at 1080.0 m. Five APC cores were taken in carbonate ooze with full recovery before chert was encountered at 43.8 mbsf. Three full-interval XCB cores then recovered a total of 1 m of core in interbedded soft ooze and chert. In an effort to recover a representative core of ooze, one additional APC core was attempted. The barrel contained 5.9 m of core, but the cutter shoe was damaged and the plastic liner had failed as a result of contact with a chert bed. The XCB then managed fair to good recovery for three cores until the chert concentration increased, resulting in lower core recovery and ROP and more XCB equipment damage with depth. Penetration was halted at 124 mbsf for a round trip for the RCB system.

Hole 749C

The hole was advanced to the coring point 102 mbsf with a center bit in place. The intercalated ooze and chert were again poorly recovered as coring continued. Basalt was penetrated at about 200 mbsf, and Core 120-749C-12R produced 5.1 m of basalt core. Only a trace of rock was recovered from the following two cores, and a round trip was made to change bits and check the coring system.

With the BHA still protected in the hole, the trip was stopped for the second FFF deployment of the leg. The funnel operation was accomplished in 2 hr, despite vessel roll and heave that reached operating limits. When the bit had cleared the seafloor, the trip was interrupted for 3-1/2 hours to wait on weather.

On completion of the pipe trip, a second failed float valve flapper was discovered. The new BHA was made up without a flapper, and the trip and reentry were made quickly.

In lieu of the missing flapper, a weighted mud program was instituted to prevent backflow of cuttings into the BHA. Two consecutive RCB cores were then taken, with 94% basalt core recovery over a 19-m interval.

At 2030 hr, 27 March, operations were suspended due to a medical emergency when Lamar Hayes, Operations Superintendent, suffered a massive heart attack.

SITE 749 TO SITE 750

As soon as the drill string was aboard, the ship departed for Fremantle for medical assistance. Mr. Hayes passed away a few hours after departure from the site, but the vessel continued to Fremantle to repatriate the body. With two days of adverse weather, the 2290 nmi voyage was made at an average speed of 11.6 kt, and JOIDES Resolution arrived at anchorage off Rottnest Island at 0700 hr, 5 April.

Transfers were made at the anchorage by helicopter and by launch. Fresh produce and emergency supplies were loaded, and a relief Operations Superintendent embarked. The vessel headed south at 1345 hr to resume operations on the Kerguelen Plateau.

Weather was much worse on the return transit, with headwinds gusting to 65 kt and combined waves reaching 50 ft. Improvement was dramatic the final 2 days, and average speed for the trip south was 10.1 kt. The beacon was launched at Site 750 at 0615 hr, 14 April.

SITE 750 (SKP-3D); EASTERN FLANK, RAGGATT BASIN

Hole 750A

Winds were gusting to 47 kt as the rig was positioned. They increased to 60 kt during the pipe trip. A seafloor "punch core" was taken, and seafloor depth was determined to be 2041.0 m. The hole was drilled ahead with "spot" cores taken at 56, 143, and 259 mbsf. Meanwhile the barometer had reached 949 mb, and combined sea and swell had built to 13-14 m. The roll limitation of the Sedco Marine Operations Manual had been reached, and it was necessary to suspend coring operations at 298 mbsf to "wait on Weather." During the 24-hr weather delay, the wind gusted to 65 kt in snow squalls, generating vessel roll to 15°.

Continuous coring resumed on the morning of 16 April in sediment that graded from near-liquid ooze to soft chalk with depth. Scattered chert stringers and nodules reduced core recovery below about 200 mbsf.

Drilling became extremely rough as soon as hard sediments were encountered at about 447 mbsf. The high torque was attributed to the excessive heave, change of formation, and/or large chert fragments in the hole. The inner core barrel was recovered at 460.5 mbsf after 3.2 m of penetration beyond the previous core. There was no core recovery, and the core catcher sub was severely damaged, obviously from junk in the hole. The core bit had failed after only about 5-1/2 rotating hr.

The hole was deep enough to require logging, so it was filled with weighted mud and the bit was released for logging. A successful seismic stratigraphy combination log was recorded from 8 m above total depth to 51 mbsf. A lithodensity log was attempted, but was unsuccessful.

SITE 751 (SKP-2C); CENTRAL RAGGATT BASIN

Hole 751A

Shifting winds gusting to 60 kt caused a 1-hr delay before continuous APC coring was begun. The coring was quite successful, considering the adverse motion conditions and the penetration of a porcellanite layer at shallow depth. After the weather delay, 161.5 m was cored with 98% recovery in just 9 hr. The good core recovery and rapid coring under adverse conditions were the direct result of an experienced and well-trained crew.

Following a 50,000-lb pullout force on Core 120-751A-18H, Core 120-751A-19H gave incomplete stroke indication. As withdrawal from the sediment was attempted, a sudden heave caused overpull to hit 120,000 lb. The piston rod failed, leaving the core barrel and core at total depth and junking the hole just short of the Oligocene objective.

RETURN TO SITE 750

Hole 750B

Unfulfilled scientific objectives lay in the older sediments and the basement, and the return to the Site 750 beacon required just 4-1/2 hr. The acoustic signal was detected without difficulty.

The upper 450 m of the section was drilled in only 10 hr with a core barrel in place. The barrel was pulled once, at 300 mbsf, to check the condition/function of the coring system. The operation then continued with "wash cores" of 19 and 28 m lengths interspersed with "real" core intervals of about 9.5 m. As Hole 750A had bottomed at the top of the indurated limestone section, the coring ROP was slower as penetration continued in firm chalk and limestone with intercalated chert. The average ROP exceeded 20 m/hr, however--an excellent rate for that lithology. Core recovery, as expected, was poor owing to the presence of chert nodules and irregular fragments of siliceous limestone. At about 590 mbsf, the drilling rate dropped to about 6 m/hr in brown claystone.

The claystone, for which the hard-formation bit was unsuited, proved to be only about 80 m thick. The final scientific goal of the voyage was reached at 672 mbsf when the bit found basaltic basement. Four basalt cores were cut before operating time ran out, with the average core recovery exceeding 60%.

SITE 750 TO FREMANTLE

The return transit to Fremantle was expedited first by unusually calm weather and then by strong quartering winds. An average speed of over 12 kt was made, enabling JOIDES Resolution to gain nearly a full day on the projected schedule. Leg 120 ended with the first mooring line at Berth A, Victoria Quay, Port of Fremantle, at 0915 hr, 30 April 1988.

OCEAN DRILLING PROGRAM
OPERATIONS RESUME
LEG 120

Total Days (21 FEB 88 - 1 MAY 88)		69.01
Total Days in Port		5.97
Total Days Under Way (including survey)		35.13
Total Days on Site		27.99
Trip Time	5.73	
Coring Time	13.21	
Drilling Time	2.23	
Logging/Downhole Science Time	1.98	
Reentry Time	0.57	
Mechanical Repair Time (contractor)	0.76	
Stuck pipe/Hole Trouble	0.86	
Wait on Weather	1.80	
Other	0.84	

Total Distance Traveled (nmi)	9206.0
Average Speed (kt)	10.9
Number of Sites	5.
Number of Holes	12.
Total Interval Cored (m)	2139.8
Total Core Recovery (m)	1081.6
Percent Core Recovered	50.5
Total Interval Drilled (m)	1406.5
Total Penetration (m)	3546.3
Maximum Penetration (m)	935.0
Maximum Water Depth (m from drilling datum)	2041.0
Minimum Water Depth (m from drilling datum)	1080.0

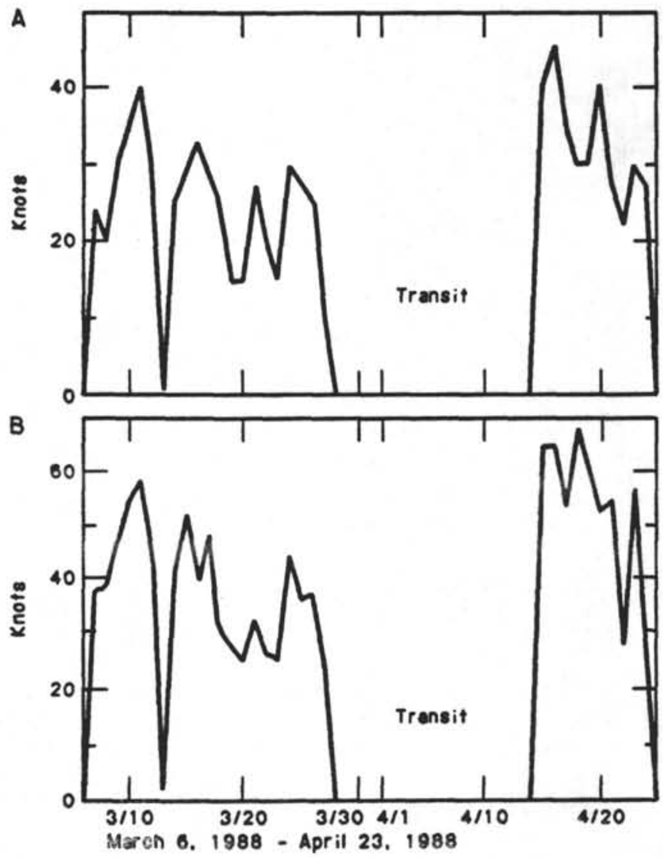


Figure 1. Average (A) and maximum (B) wind conditions during Leg 120.

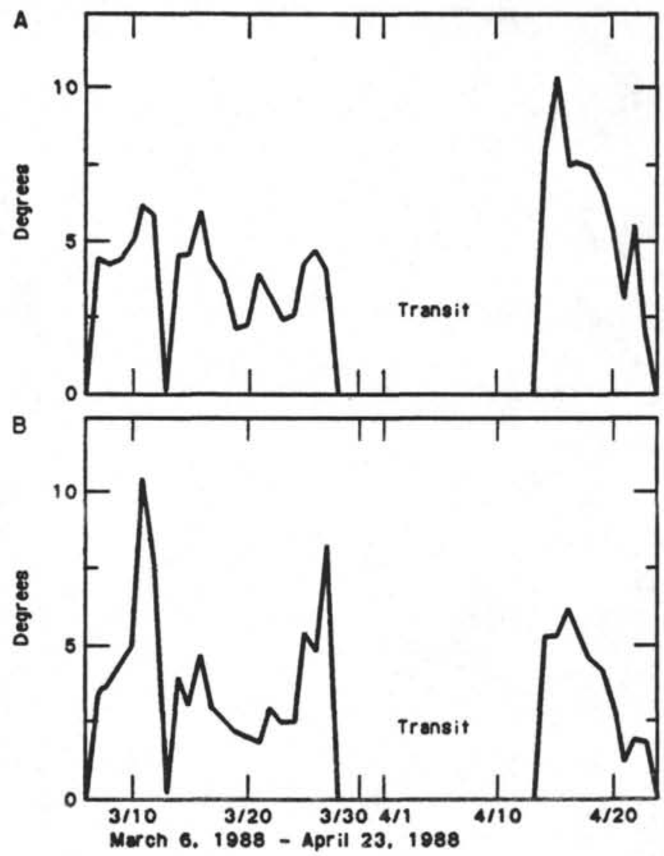


Figure 2. (A) Drillship pitch conditions during Leg 120.
(B) Drillship roll conditions during Leg 120.

TECHNICAL REPORT

The ODP Technical and Logistics personnel aboard JOIDES Resolution for Leg 120 of the Ocean Drilling Program were:

Laboratory Officer:	Brad Julson
Computer System Manager:	Larry Bernstein
Curatorial Representative:	Paula Weiss
Yeoperson:	Michiko Hitchcox
Electronics Technician:	Mike Reitmeyer
Electronics Technician:	Barry Weber
Photographer:	Chris Galida
Chemistry Technician:	Matt Mefferd
Chemistry Technician:	Joe Powers
Marine Technician:	Wendy Autio
Marine Technician:	Jenny Glasser
Marine Technician:	Dennis Graham
Marine Technician:	Ted Gustafson
Marine Technician:	Jim Hollick
Marine Technician:	Kevin Rogers
Marine Technician:	Christian Segade
Marine Technician:	Don Sims

INTRODUCTION

Leg 120 began 21 February 1988 in Fremantle, Australia and ended there 69 days later on 30 April 1988. Twelve holes were drilled at five sites. Over 1081 m of core was recovered from which more than 10,000 samples were taken for shipboard and shore-based analyses. In addition, two holes were logged.

PORT CALL - FREMANTLE I

The ship arrived in Fremantle on 21 February at 0600, and technician crossover commenced shortly thereafter. In addition to the usual air and surface freight, the bridge received a new multicolor radar system. Marisat repairs continued throughout the port call, ultimately requiring that a critical part be handcarried from the U.S. IFP engineers installed a motion compensator recording package and stayed aboard for a few hours after sailing to ensure its proper functioning; they departed the ship via a hired launch. A French technician planned to sail on the leg with a new downhole magnetic susceptibility tool. Unfortunately, only two of its three pieces arrived by the time of departure and he therefore disembarked before the ship sailed.

CRUISE ACTIVITIES

The ship departed Fremantle at 2345 hr on 26 February. Magnetometer and bathymetry data were collected during all the transits except in extremely rough weather. Expendable bathythermographs (XBT's) were deployed four times a day during the transits to collect seawater temperature data.

A medical emergency required that we leave Site 749 the night of 28 March and immediately steamed for Fremantle. We rendezvoused with a helicopter off Rottnest Island and then returned to Site 750. Owing to this unforeseen transit, the leg was extended 4 days.

LABORATORY ACTIVITIES

Curation

Over 10,000 samples were collected during Leg 120. Sampling and testing were done on "geriatric" cores collected on Leg 119. There were a number of special requests for this leg, including sampling of a partially preserved K/T boundary from Hole 751A, and U-channel sampling for paleomagnetics, also from Hole 751A.

Bridge Deck

Core Lab

In many Leg 120 cores, chert stringers occurred in soft ooze layers, creating difficulties in splitting the cores. A novel method was developed in which first the liner is split using the splitter with the wire removed, then the chert is removed and cut with the rock saw, the ooze is split with the wire in place, and the chert is returned to the core. Although time-consuming, this method resulted in minimal disturbance to the sediments.

Magnetics

During the leg, archive halves of core were routinely measured with the cryogenic magnetometer and discrete samples with the Minispin magnetometer. A new temperature controller switch for the chilled water lines was installed. It was discovered that some of the cores seemed to be picking up a second, different, magnetic signal after being cut. Furthermore, the quartz magnetic boat possessed half as much signal as some of the weaker samples. Programming will need to be developed to subtract this out. A belt was changed in the Minispin and spin cycles were returned to the normal length.

Physical Properties

Many software changes were implemented in the physical properties lab to increase the speed of data entry. The 2-min GRAPE program was debugged and a sample holder was developed. Owing to the cold, core temperatures equilibrated to room temperatures more slowly than normal. A regulator was replaced in the GRAPE and the unit ran well afterward.

Foc'sle Deck

Chemistry

A new natural gas analyzing gas chromatograph was installed that can quickly analyze hydrocarbons as well as elemental gases. The Dionex IC system was cleaned, following problems during Leg 119. A micromembrane suppressor was installed and this also improved the baseline. A new oxidation oven was installed in the Rock Eval, but the technicians were unable to fix the TOC module. A new program is being written using LOTUS 1-2-3 to quickly load chemistry data into CHEMDB. The labstack water quality is still poor and efforts are under way to improve it.

Thin Sections

Over 100 thin sections were produced, a result of high basement recovery. The LP-30 worked well but a resin chamber on the impregnation unit imploded. These will be taken back to Logitech to investigate for a structural flaw.

X-Ray

The XRD was used for about 150 samples and the XRF was used for 50 basalt samples and a few sediment samples. The XRD's tube intensity had decreased to the point at which replacement was necessary. The XRF's second goniometer was calibrated and programs were written to run both goniometers simultaneously, which should decrease run times by about a third.

SEM

Despite the rough seas the SEM was used by sedimentologists and paleontologists. The SEM worked well for imaging at high magnifications but photography was severely limited by the sea state.

Other Areas

Storekeeper

A new MATMAN update arrived and is highlighted by menu-driven programs. Storekeeper guidelines were written, as was a guide to the gas bottle inventory. The ship's stores did a brisk business, though stock was extremely low. For the first time, a French postage stamp featuring JOIDES Resolution was offered for sale.

Downhole Tools

Heat-flow temperature measurements were performed with the "Uyeda" style probe without the pore-water attachment. Seven runs were made, the majority being freefall drops. Six of the runs were successful, although most indicated some degree of tool motion owing to heavy seas.

Underway Geophysics

The guns were used on site surveys with no problems. No icing problems were experienced during these transits. Quick connects and large snap hooks attached to long poles helped the technicians safely deploy and retrieve the guns. The 400 $in.^3$ gun was rigged for possible VSP work planned at some of the sites but was not used owing to time constraints. Sonobuoy batteries were also checked but not used owing to the heighth of the seas. The magnetometer experienced problems but was successfully repaired with a Geometrics rebuild kit. Four excellent magnetic lines were collected from the transits to and from the Kerguelen Plateau.

The underway geophysics lab was used extensively during the four long transits that covered over 9000 nmi. The Magnavox 1107 ran well with minor errors. The Smooth program is becoming unwieldy to use with large data sets and is a difficult tool for scientists. A marine technician brought aboard programs which proved much more useful for scientists' needs and which will be considered further on shore. In the rough seas the PDR signals were indiscernible from the ship's noise at all but the slowest speeds. Two new wirelines were run from the ship's forward thyrig room aft to the U/W lab in preparation for the new transducer pod that will be installed in Singapore. Finally, the FPP board was installed in the 85 mbte Masscomp system.

Reentries

Two minicones were dropped and two effortless, fast reentries were performed. The rigging of the VIT camera proved satisfactory.

Photo Lab

The main problem the photo lab suffered was minor flooding from leaks in the HVAC ducting. This was remedied with a plastic trough built to catch and funnel the water. Water quality was a problem especially in the hot water lines. Water samples and filters are being taken back to the beach to be analyzed in order to find solutions to our water problems. The 3/4-in. video camera was sent back for repairs.

Computer Facilities

The system manager analyzed system performance regarding memory management and resource utilization. A system was created for using various laser fonts on the QMS for VAX text files. Eighteen of the ship's PRO-350s were replaced by new IBM PC/AT clones during the post-cruise port call.

Weather

The weather during Leg 120 was probably the most severe experienced to date. Sleet and snow were common, as were waves in excess of 20 m, winds over 65 kt and rolls over 20°. The ship spent 1.8 days waiting on weather, and the weather was responsible for bit failure in two holes. Weather forecasting by the Captain and mates was aided by satellite photos and maps from NOAA, Australia, and a Russian Antarctic weather station.

Safety

The ship had weekly fire and boat drills, and the METS practiced weekly with the SEDCO fire fighting crew. The ship's physician held medical seminars on selected topics and also conducted CPR classes. New fiberglass lockers arrived for firefighting turnouts and survival equipment.

Personnel

The extremely rough sea conditions strained everyone during the leg. Lack of sunlight and the freezing, blowing weather made for a long, difficult trip. Lamar's passing away was a crushing blow that weighed heavily on all of us. But throughout all of this the crew persevered and spirits remained high. The entire team is to be congratulated for their professionalism and a job well done.