1. INTRODUCTION[1]

Shipboard Scientific Party[2]

INTRODUCTION

Legs 119 and 120 of the Ocean Drilling Program (ODP) were planned to complete a latitudinal transect in the Southern Ocean between Kerguelen Island (49°S) and Prydz Bay, Antarctica (67°S). These two legs were proposed 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 southern Central Indian Ocean. 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 (Fig. 1). The plateau stretches approximately 2300 km between 46°S and 64°S in a northwest-trending direction toward the Antarctic continental margin. The feature is between 200 and 600 km wide and stands 2–4 km above the adjacent ocean basins.

Most of the Kerguelen Plateau lies south of the present-day Polar Front (Antarctic Convergence) and beneath the main flow of the Antarctic Circumpolar Current (Fig. 2). Drilling on the Kerguelen Plateau, therefore, should 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, is located between 46°S and 54°S. This portion generally lies in <1000-m water depths, and it 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 (water depths are generally between 1500 and 2000 m) and displays a much more subdued topography.

The transition zone exhibits a complex bathymetry with a large east-trending spur, the Elan Bank, extending westward from the main plateau over a distance of 600 km. The northeastern flank of the plateau is extremely steep and almost linear, especially to the north; the topography of the southwestern flank is more complicated, but it generally has a gentler slope.

A recent bathymetric chart, drawn at a scale of 1/5,000,000 at the equator, has been jointly edited by the Bureau of Mineral Resources, Canberra, Australia; the Institut de Physique du Globe, Strasbourg, France; and the Territoire des Terres Australes et Antarctiques Francaises, Paris, France (Schlich et al., 1987). The chart covers the whole Kerguelen Plateau and takes into account most of the existing bathymetric data (Fig. 3). The overall morphology of the plateau, as described above, is clearly expressed; moreover, the northeastern flank of the plateau appears even steeper on this new bathymetric chart and follows almost exactly, to the north and to the south, the direction of the present Southeast Indian Ridge axis.

The age of the oceanic crust abutting the plateau varies and has been analyzed since 1966 by various authors. The Kerguelen Plateau and Broken Ridge form a symmetric pair of "aseismic ridges" separated by the Southeast Indian Ridge. Fracture zones and magnetic lineations related to this spreading center have been mapped and analyzed by Schlich and Patriat (1967, 1971b), Le Pichon and Heirtzler (1968), McKenzie and Sclater (1971), Schlich (1975), and Houtz et al. (1977). Furthermore, the seafloor close to the Kerguelen Plateau has been dated by the observed magnetic lineations (Fig. 1).

Schlich and Patriat (1967, 1971b) recognized Anomalies 1–11 (32 Ma) to the east and to the north of Kerguelen Island. Le Pichon and Heirtzler (1968) identified Anomalies 13, 16, and 17 (41 Ma) east of Heard Island. Farther to the south, eastward from Heard Island, Houtz et al. (1977) also identified Anomalies 1–18 (42–43 Ma). Thus, the isochrons close to the northeastern margin of the Kerguelen-Heard Plateau vary in age from 32 Ma (to the north) to 42–43 Ma (to the south).

Northwest and west of the Kerguelen Plateau, Magnetic Anomalies 23, 24, 26, and 28 (65 Ma) and Magnetic Anomalies 33 and 34 (84 Ma) have been identified by Schlich (1975, 1982). No seafloor magnetic anomalies have been observed adjacent to the southwestern flank of the Kerguelen Plateau. To the south, the eastern flank of the Southern Kerguelen Plateau is bounded by the deep Labuan Basin (Coffin et al., 1986), which has not been dated but which probably corresponds to Mesozoic oceanic crust. All the ages given in this section are derived from the magnetic time scale proposed by Berggren et al. (1985).

According to Le Pichon and Heirtzler (1968), the Kerguelen Plateau and Broken Ridge separated in Eocene time. The reconstructions proposed by Houtz et al. (1977) and Goslin (1981), which allow for the total closure of Australia and Antarctica at Anomaly 20, show an unacceptable overlap of Broken Ridge and the Northern Kerguelen Plateau, considering the oldest sediments that were recovered by coring and drilling on these two features (Quilty, 1973; Luyendyk and Davies, 1974). Mutter and Cande (1983) and Mutter et al. (1985), employing a revised chronology for the breakup of Australia and Antarctica (Cande and Mutter, 1982), partially resolved the overlap problem. However, the resulting reconstruction does not exclude an overlap of the northern portion of the Kerguelen Plateau with Broken Ridge.

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: (1) it is a continental fragment left over from the breakup of India and Antarctica; (2) it is a product of excessive on- or off-axis oceanic volcanism, possibly hot-spot related (oceanic-island-type

[1] Schlich, R., Wise, S. W., Jr., et al., 1989. *Proc. ODP, Init. Repts.*, 120: College Station, TX (Ocean Drilling Program).

[2] Shipboard Scientific Party is as given in the list of Participants preceding the contents.

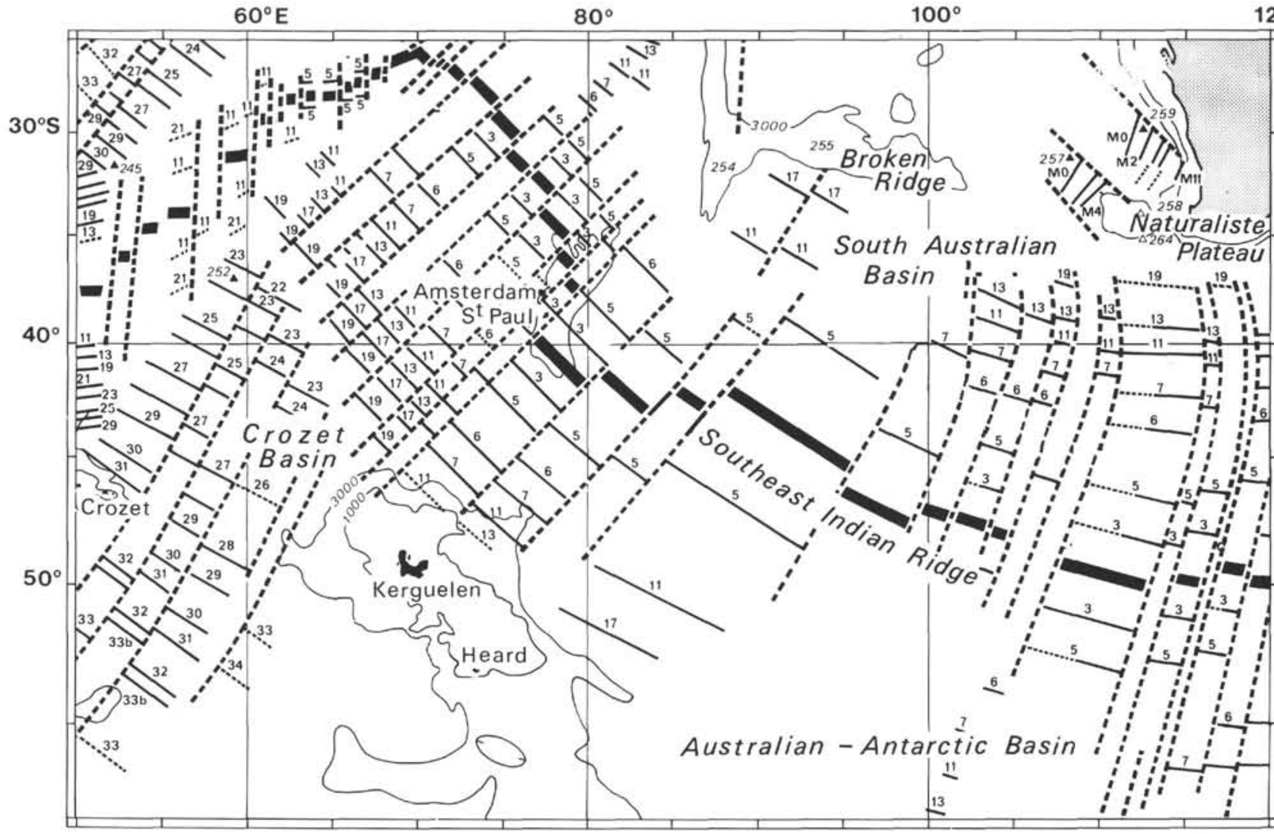

Figure 1. The Kerguelen Plateau in the southern Central Indian Ocean. Bathymetry in meters is from GEBCO (Hayes and Vogel, 1981; Fisher et al., 1982). Fracture zones and magnetic lineations are from Schlich and Patriat (1967, 1971a, 1971b), Le Pichon and Heirtzler (1968), Schlich (1975, 1982), and Houtz et al. (1977).

volcanism); or (3) it is a thermally or tectonically uplifted block of oceanic crust (mid-oceanic-ridge-type volcanism).

None of these possibilities may be eliminated at present, and it is 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. Petrological (Giret, 1983) and geochemical studies (Dosso et al., 1979; Mahoney et al., 1983) on Kerguelen Island rocks show clear affinities with the observations derived from other oceanic islands.

The crustal structure of the Southern Kerguelen Plateau was modeled by Houtz et al. (1977) using gravimetric and seismic reflection/refraction data, and that of the Kerguelen-Heard Plateau by Recq et al. (1983) and Recq and Charvis (1986) using two refraction profiles shot on Kerguelen Island. The maximum thickness of the crust was determined to lie between 15 and 23 km. Furthermore, the seismic velocity vs. depth distribution is similar to that of typical oceanic islands (Crozet) or plateaus (Madagascar).

More recently, Recq and Charvis (1987) proposed a gravimetric interpretation based upon gravimetric measurements on Kerguelen Island and upon GEOS 3 and SEASAT altimetric data. They used a Pratt-type compensation model with a compensation depth at 50 km and concluded that the Kerguelen Plateau and its symmetric feature, Broken Ridge, originated near a spreading center by excessive volcanism related to a thermal anomaly in the lithosphere beneath Kerguelen Island.

Bradley and Frey (1988) have analyzed the MAGSAT data associated with the Kerguelen Plateau and Broken Ridge. Assuming for their model that the two features are structurally similar and underlain by oceanic crust, they concluded that the Curie isotherm rises to a depth of about 15 km within the crust to the north beneath Kerguelen and Heard islands. This result supports the suggested thermal anomaly (Recq and Charvis, 1987).

Recent Geophysical and Geological Surveys

American, Soviet, French, and Australian research ships have surveyed the Kerguelen Plateau. The most recent contributions are from the French *Marion Dufresne* (1981, 1983, 1986) and the Australian *Rig Seismic* (1985) cruises. The first cruises, prior to 1981, collected bathymetric, magnetic, gravimetric, single channel seismic (SCS) reflection profiles, sonobuoy wide-angle reflection and refraction data as well as piston cores. The first bathymetric charts and the sediment distribution on the Kerguelen Plateau were derived from these reconnaissance studies (Schlich et al., 1971; Schlich, 1975; Houtz et al., 1977).

The 1981 *Marion Dufresne* cruise (MD26) provided high-quality multichannel seismic reflection (MCS) data over an area of about 80,000 km^2 on the Kerguelen-Heard Plateau, southeast of Kerguelen Island. Five northeast-southwest profiles and five orthogonal northwest-southeast profiles were shot; the profile spacing was about 50 km. A total of 2640 km of 24-channel seismic reflection profiles were obtained using a 2400-m streamer and a Flexichoc source with a 50-m shot interval (Fig. 4).

Two sonobuoy experiments (01MD26, 02MD26) on seismic lines MD26-11 and MD26-12, respectively, were performed during this cruise (Fig. 5). In addition, 14 piston cores (81317–81330), located on seismic lines MD26-07 and MD26-10, were obtained along the northeastern flank of the Kerguelen-Heard Plateau (Fig. 6).

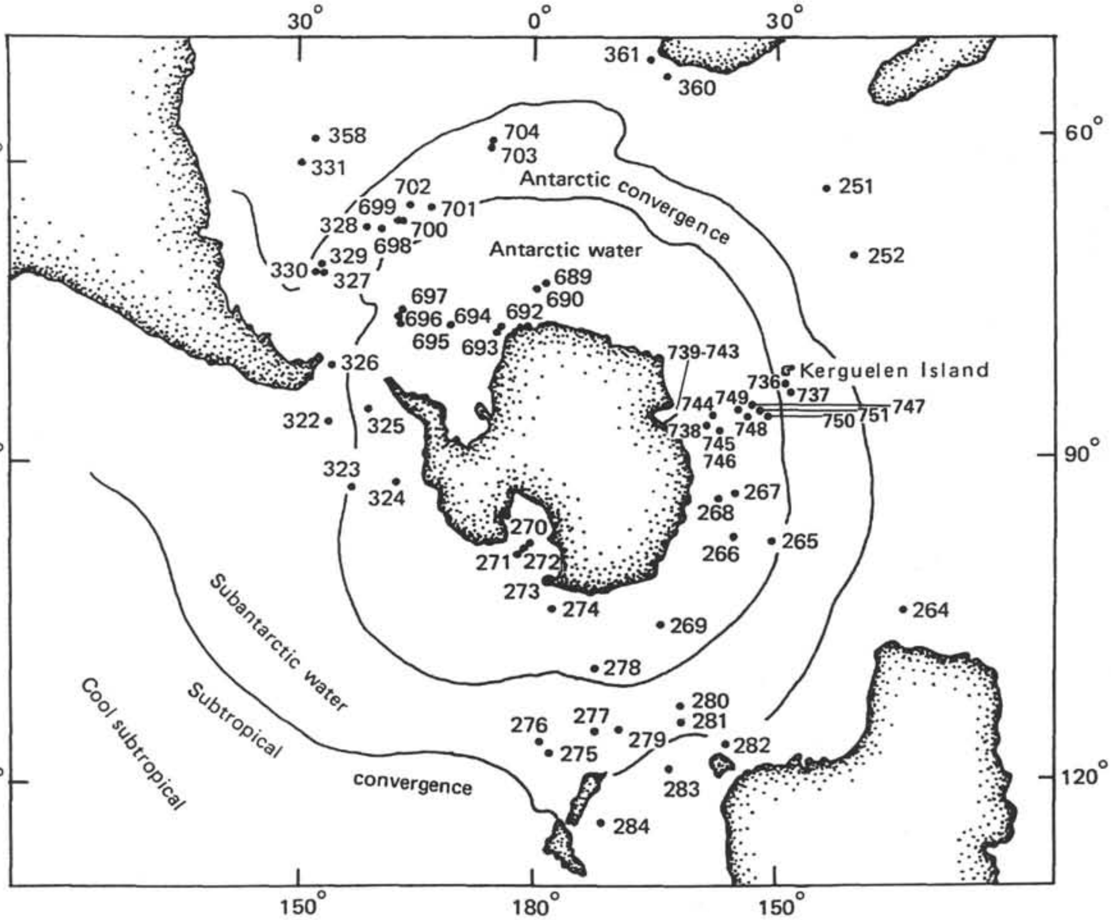

Figure 2. Present-day location of surface-water masses of the Southern Ocean (Kennett, 1978). Numbers indicate Deep Sea Drilling Project (DSDP) and Ocean Drilling Program (ODP) sites.

The 1983 *Marion Dufresne* cruise (MD35) provided 42 piston cores (83479–83520) and three dredge hauls (83DR01–83DR03), located on the eastern and western flanks of the Kerguelen-Heard Plateau at a latitude of about 50°S (Fig. 6).

The 1985 *Rig Seismic* cruise (RS02) acquired high-quality multichannel seismic reflection (MCS) data over the Kerguelen Plateau between 50°S and 60°S. Most of the lines were shot in a west-southwest to east-northeast direction; the spacing of the seven east-west profiles on the Southern Kerguelen Plateau was roughly 50 km. A total of 5600 km of 48-channel seismic reflection profiles were obtained using a 1200-m streamer with two 500-in^3 air guns fired at 50-m intervals (Fig. 4). One sonobuoy experiment (01RS02) was performed during this cruise along line RS02-29 (Fig. 5). Minor sampling was undertaken with free-fall grab samplers (01RS02) over a prominent fault scarp, the 77°E Graben, intersected by line RS02-24 (Fig. 6); two of these recovered a few samples of igneous rocks.

The first 1986 *Marion Dufresne* cruise (MD47) surveyed the entire Southern Kerguelen Plateau between 55°S and 63°S and provided 4450 km of 24-channel seismic reflection profiles, using a 2400-m streamer and a Flexichoc source with 50-m shot intervals. The profiles were shot in the central part of the Southern Kerguelen Plateau to be orthogonal to the *Rig Seismic* 1985 lines (Fig. 4). Four sonobuoy experiments (01MD47–04MD47) were performed during this cruise over representative sedimentary sequences; these sonobuoys were launched on seismic lines MD47-11, MD47-13, MD47-14, and MD47-15 (Fig. 5).

The second 1986 *Marion Dufresne* cruise (MD48) provided 16 piston cores (86696–86711) and 8 dredge hauls (86DR01–86DR08), located along the eastern flank of the Kerguelen-Heard Plateau close to the proposed site KHP-3 (86696, 86DR08), east of Heard Island (86710, 86711, 86DR01), and on the central part of the Southern Kerguelen Plateau at the intersection of seismic lines MD47-04 and RS02-13 (86708, 86709, 86DR07), on seismic lines MD47-14 (86697), RS02-19 (86704, 86705, 86DR02–86DR04), and RS02-22 (86698–86703). All these sites were selected on the basis of the multichannel seismic reflection profiles obtained during the 1985 *Rig Seismic* cruise and the 1981 and 1986 *Marion Dufresne* cruises. The locations of the sites are given on Figure 6.

The Evolution of the Kerguelen-Heard Plateau

The structure of the Kerguelen-Heard Plateau, or Northern Kerguelen Plateau, and sediment distribution were first described by Schlich et al. (1971), Schlich (1975), and Houtz et al. (1977); the results were based upon the seismic reflection data obtained by the *Gallieni* (1970, 1972) and *Eltanin* (1971, 1972) cruises. The large sedimentary basin located on the plateau southeastward of Kerguelen Island has been analyzed in some detail by Guglielmi (1982), Wicquart (1983), Frohlich et al. (1983), Wicquart and Frohlich (1986), Frohlich (1986), and Munschy and Schlich (1987) using the geophysical and geological data acquired in 1981 (cruise MD26) and 1983 (cruise MD35).

The average sediment thickness in the basin on the Kerguelen-Heard Plateau is about 2000–2500 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 (Fig. 7). The upper mega-

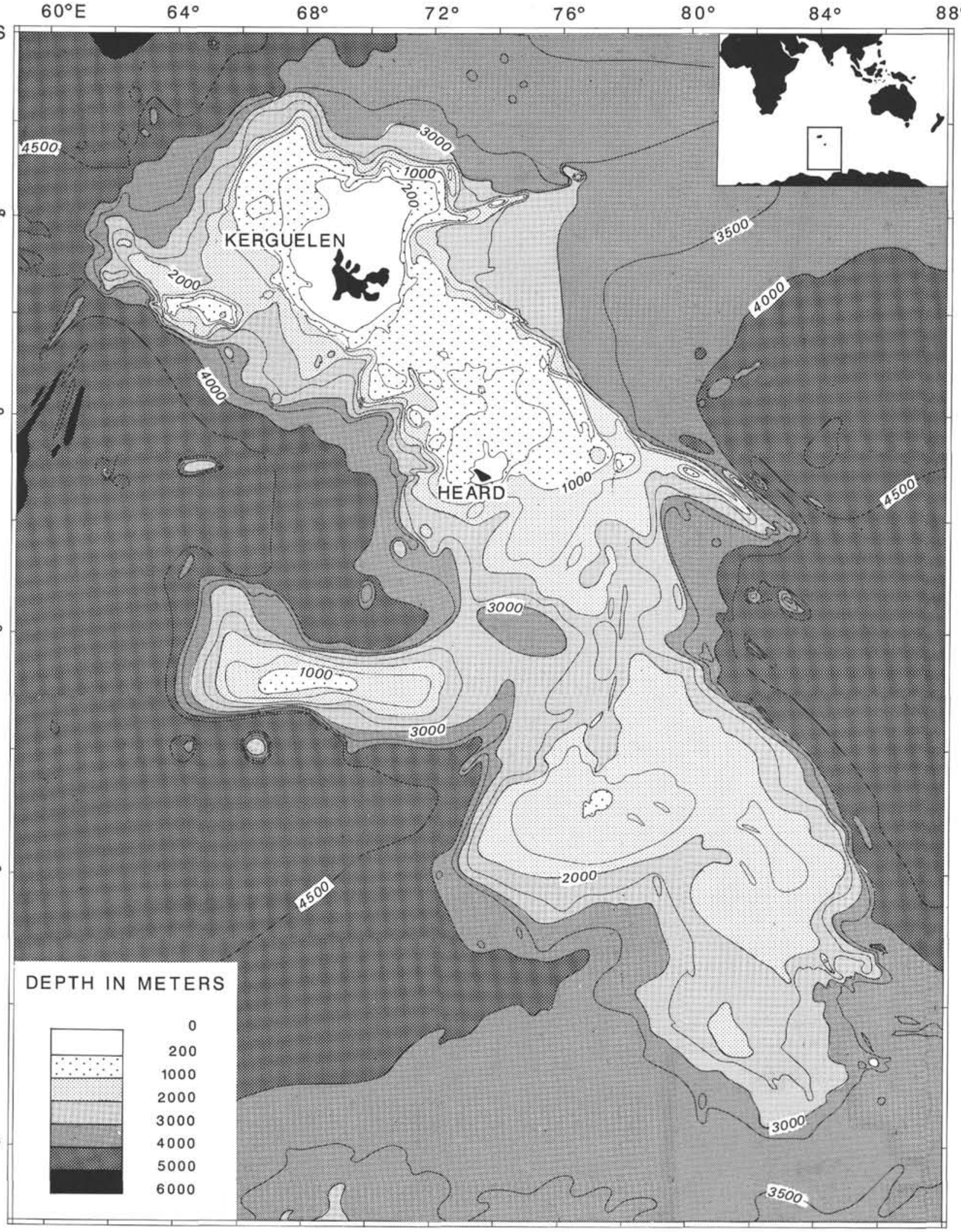

Figure 3. Bathymetric chart of the Kerguelen Plateau after Schlich et al. (1987). The contour interval is 500 m.

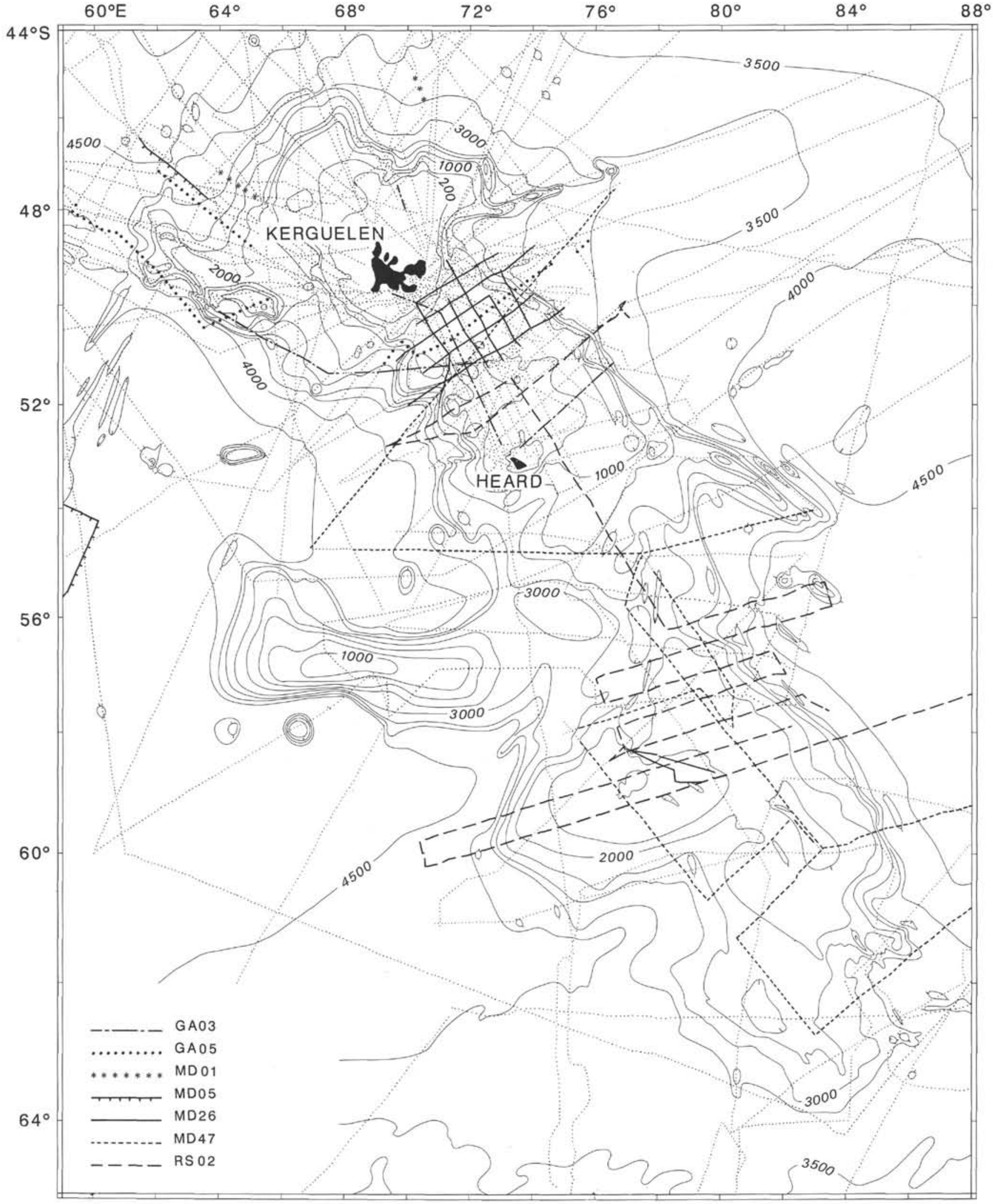

Figure 4. Track lines on the Kerguelen Plateau. Bold lines denote MD26 (1981), RS02 (1985), and MD47 (1986) multichannel seismic reflection profiles.

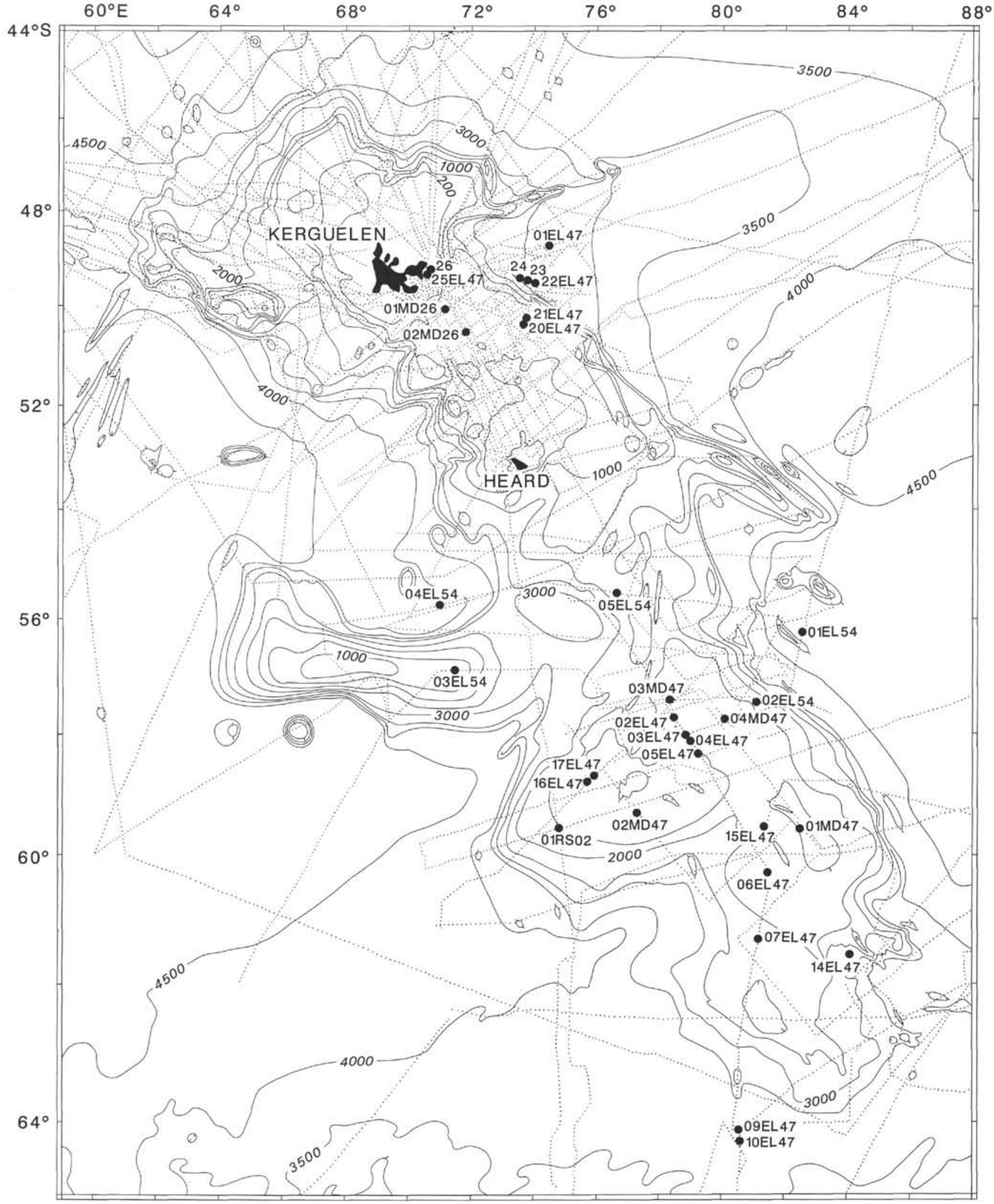

Figure 5. Location of sonobuoy experiments on the Kerguelen Plateau. *Eltanin* cruises EL47 and EL54 (Houtz et al., 1977); *Marion Dufresne* cruise MD26 (Guglielmi, 1982); *Rig Seismic* cruise RS02 (Ramsay et al., 1986); and *Marion Dufresne* cruise MD47 (unpubl. data).

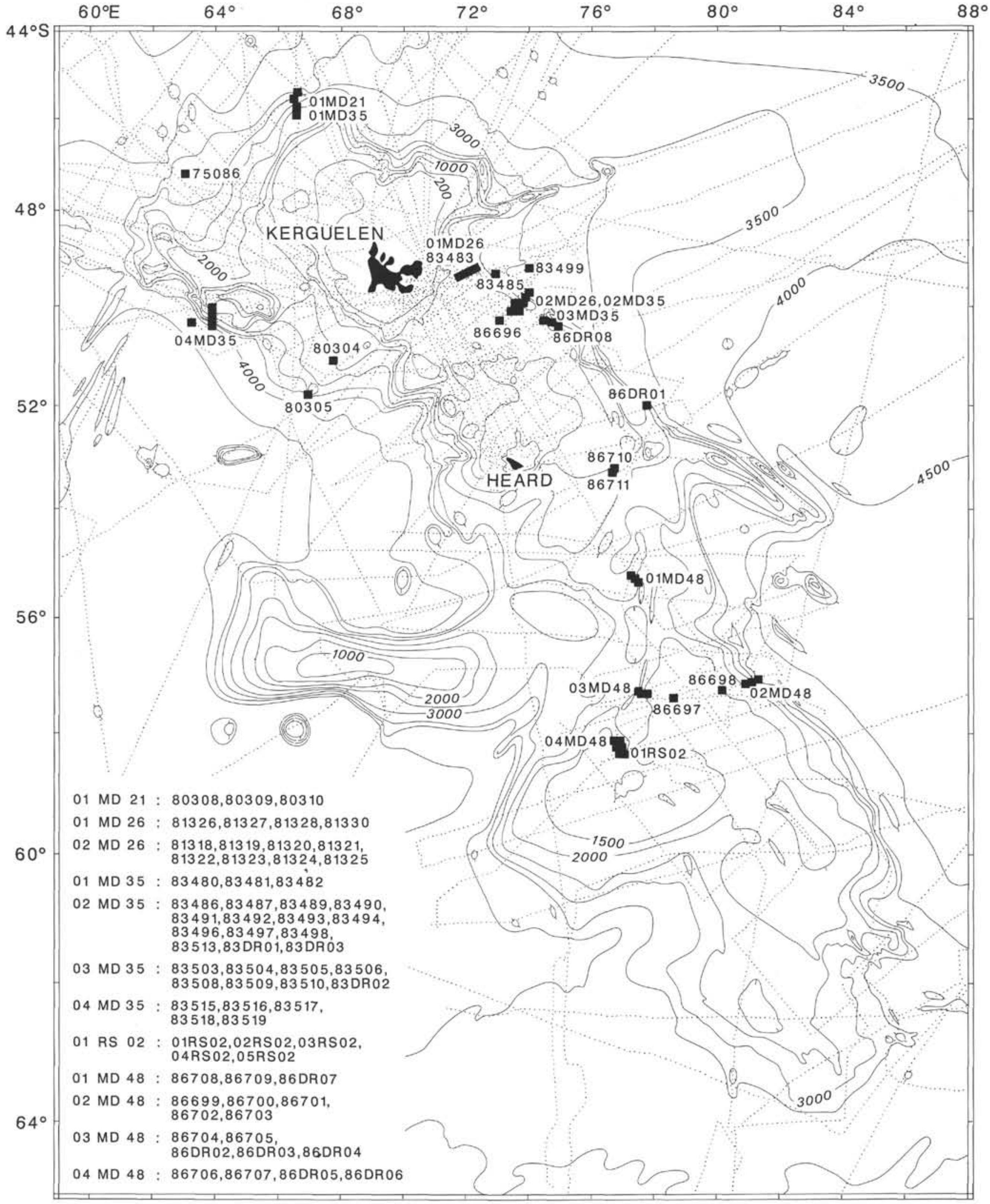

Figure 6. Location of piston cores and dredge hauls on the Kerguelen Plateau. *Eltanin* cruise EL54 (Houtz et al., 1977; Quilty, 1973); *Marion Dufresne* cruises MD26 and MD35 (Wicquart, 1983; Wicquart and Frohlich, 1986); *Rig Seismic* cruise RS02 (Ramsay et al., 1986); and *Marion Dufresne* cruise MD48 (Leclaire et al., 1987a, 1987b).

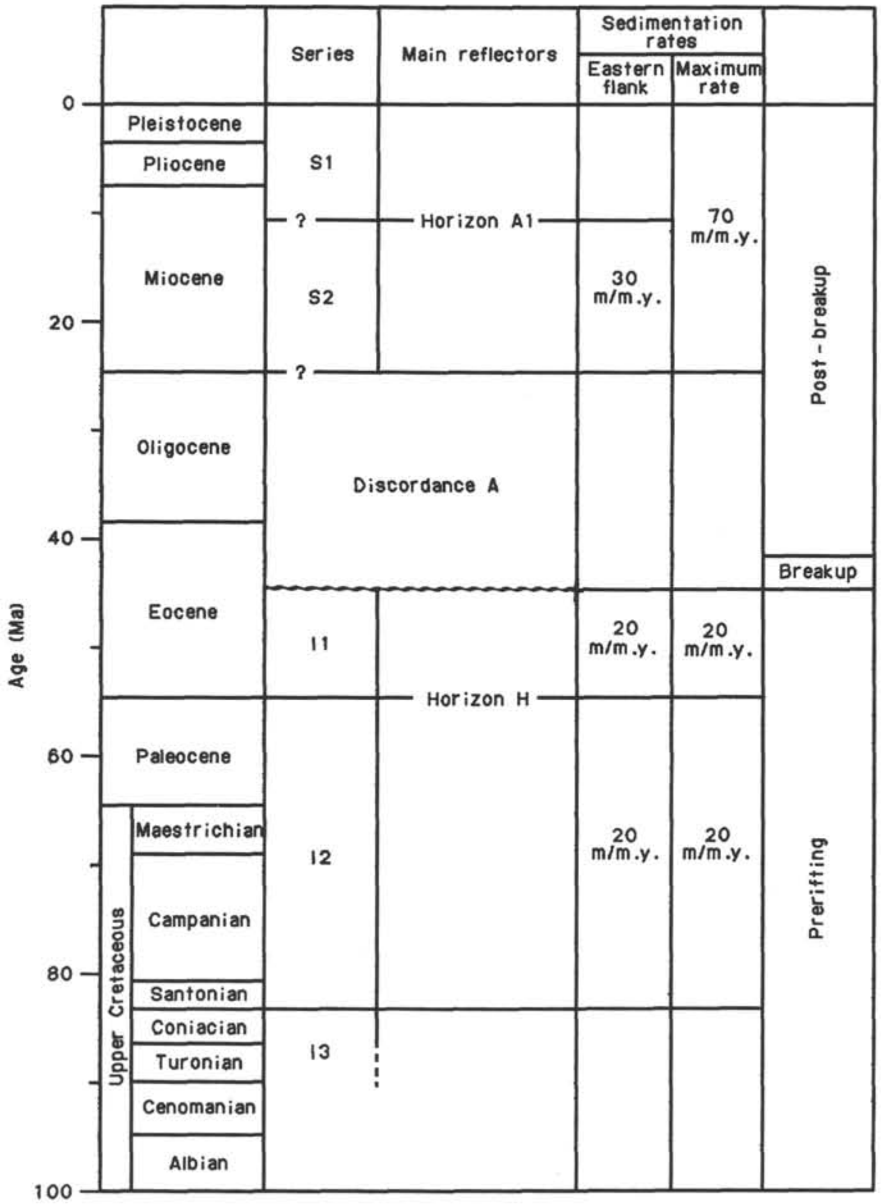

Figure 7. Seismic sedimentary units identified on the Kerguelen-Heard Plateau with corresponding ages and sedimentation rates (Munschy and Schlich, 1987).

sequence S is divided into two units (S1 and S2) by the discordance A1. 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 prerifting sequences from breakup and post-breakup sequences. Figure 8 displays three cross sections of the Kerguelen-Heard Plateau derived from seismic interpretation.

The evolution of the Kerguelen-Heard Plateau, postulated from basin stratigraphy and based upon piston-core age determinations (Wicquart, 1983; Wicquart and Frohlich, 1986), can be summarized as follows (Munschy and Schlich, 1987):

1. In early Late Cretaceous (130–100 Ma), the Kerguelen-Heard Plateau was faulted and elevated to shallow depths. Normal faulting occurred along the present limit of the sedimentary basin and along the present eastern margin of the plateau. This tectonic event corresponds to the first prerift faulting episode between the Kerguelen Plateau and Broken Ridge (Fig. 9A).

2. From Late Cretaceous to Eocene, the Kerguelen-Heard Plateau remained a shallow marine structure, continuously subsiding at a rate of about 20 m/m.y., and was covered essentially by shelf pelagic sediments (units I2 and I1) without an obvious sedimentary hiatus. Unit I3 represents the first deposition on the Kerguelen-Heard Plateau platform (Fig. 9B).

3. During the Eocene the eastern part of the Kerguelen-Heard Plateau was uplifted, probably close to sea level, and unit I1 was partially eroded (Fig. 9C).

4. At the time of Anomaly 18 (43–42 Ma), the Kerguelen-Heard Plateau and Broken Ridge were clearly separated by spreading at the Southeast Indian Ridge. The breakup occurred

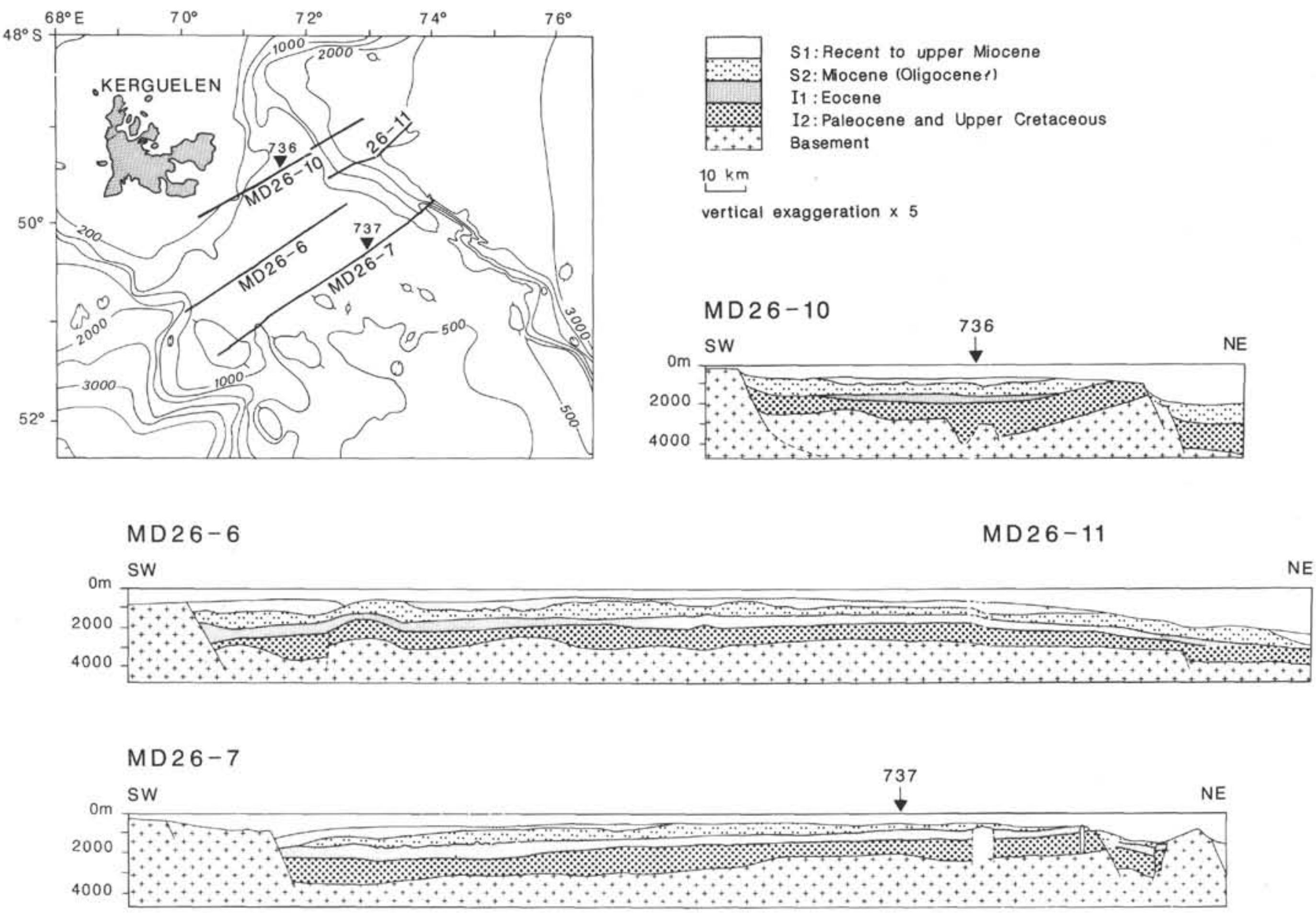

Figure 8. Cross section of the Kerguelen-Heard Plateau derived from seismic interpretation (Munschy and Schlich, 1987).

45–42 m.y. ago, and the newly rifted margins subsequently subsided. A major gap of sedimentation characterizes the period between middle Eocene and late Oligocene–early Miocene.

5. During Miocene and possibly Oligocene time, the plateau was covered by calcareous oozes containing siliceous biogenic components. The clastic part of the postrift deposits is significant and is derived essentially from Kerguelen Island. The first clastic deposits are probably Oligocene in age (Fig. 9D).

6. Sedimentation continued throughout the late Miocene, Pliocene, and Pleistocene and consists of diatomaceous oozes, glauconized sands with ice-rafted debris, and ash layers corresponding to explosive volcanic activity (Fig. 9E).

The Evolution of the Southern Kerguelen Plateau

The structure of the Southern Kerguelen Plateau and the sediment distribution were first described by Houtz et al. (1977) and were based upon geophysical and geological data collected by *Eltanin* in 1971 and 1972. Three recent research cruises, *Rig Seismic* 02 (1985) and *Marion Dufresne* 47 and 48 (1986), yielded new information for understanding the structure and evolution of the Southern Kerguelen Plateau (Ramsay et al., 1986; Coffin et al., 1986; Leclaire et al., 1987a, 1987b; Schlich et al., 1988; Colwell et al., 1988; Coffin et al., in press).

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-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 that are flanked by a large abyssal plain, the Labuan Basin (Ramsay et al., 1986).

From an analysis of the SEASAT-derived free-air gravity field and the 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 (Fig. 10). Other striking features, clearly expressed to the south, are basement highs which divide the central and southern parts of the Southern Kerguelen Plateau into several distinct sedimentary domains. The most developed sedimentary basin is the large Raggatt Basin to the east.

Dredging along the 77°E Graben recovered the first significant assemblage of basement rocks from the Southern Kerguelen Plateau (Leclaire et al., 1987a, 1987b). The horst samples are basaltic and are chemically and isotopically of ocean island affinity rather than ridge affinity; a K-Ar age of the basalt is about 114 Ma, corresponding to the Aptian Stage of the Early Cretaceous (Leclaire et al., 1987a). The lowermost exposed sediments are of Late Cretaceous to Paleogene age and are separated from the upper Eocene to Oligocene calcareous nannofossil oozes and Neogene to Pleistocene calcareous and siliceous oozes by a horizon of interbedded cherts (Leclaire et al., 1987b).

The sediment thickness in the Raggatt Basin on the Southern Kerguelen Plateau is about 2500–3000 m. Schlich et al. (1988)

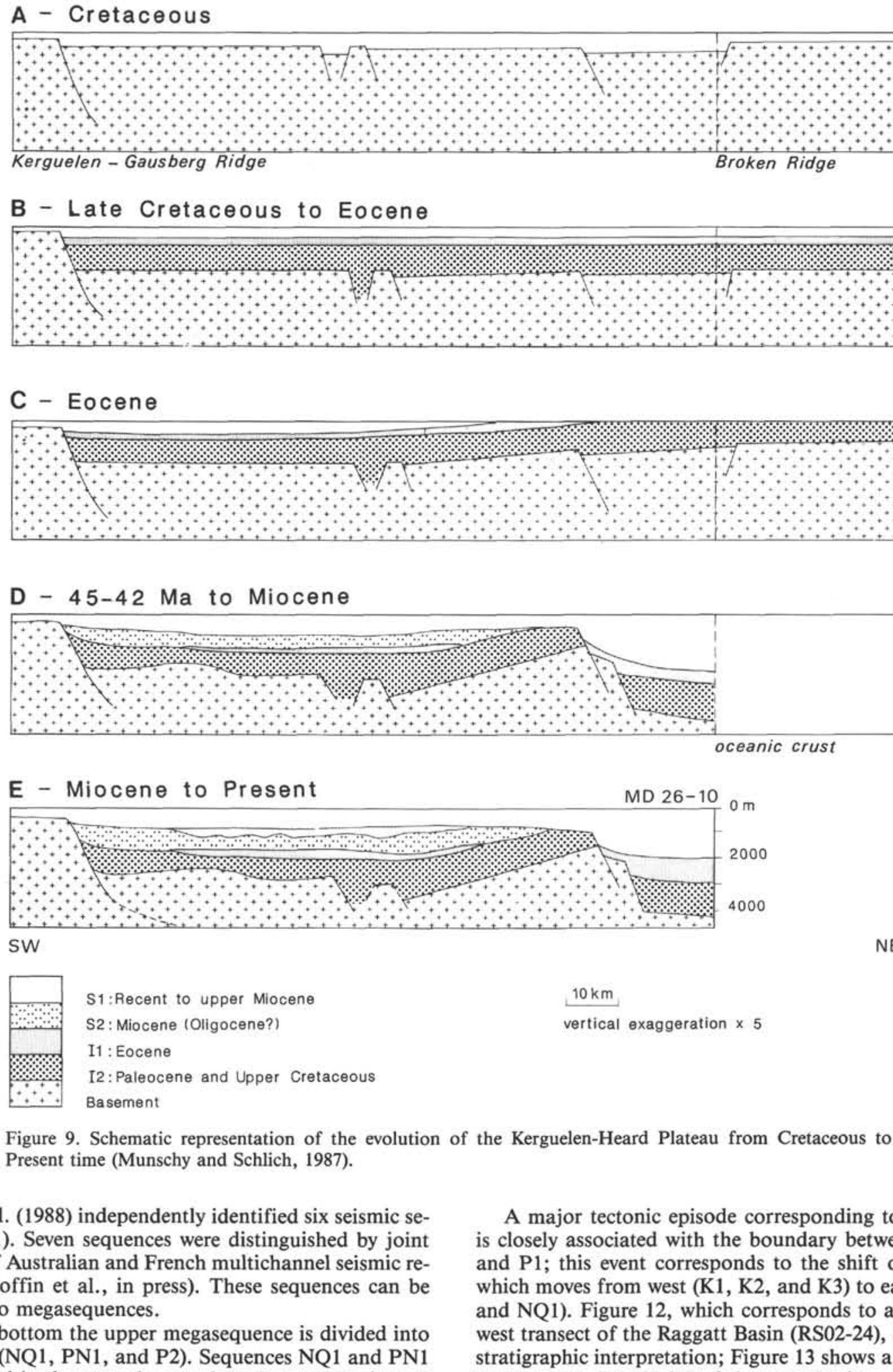

Figure 9. Schematic representation of the evolution of the Kerguelen-Heard Plateau from Cretaceous to Present time (Munschy and Schlich, 1987).

and Colwell et al. (1988) independently identified six seismic sequences (Fig. 11). Seven sequences were distinguished by joint interpretation of Australian and French multichannel seismic reflection data (Coffin et al., in press). These sequences can be grouped into two megasequences.

From top to bottom the upper megasequence is divided into three sequences (NQ1, PN1, and P2). Sequences NQ1 and PN1 are only observed in the central part of the Raggatt Basin and are truncated in all directions by toplap. Sequence P2 filled the relief of the lower megasequence by onlap.

The lower megasequence is divided from top to bottom into four sequences (P1, K3, K2, and K1). Sequences P1 and K3 are characterized by mounds that appear either as isolated features or in association with normal faults. The thickness of Sequence P1 remains fairly uniform in the basin while Sequence K3 shows significant variations in thickness. Sequences K2 and K1 fill the center of the basin and disappear in all directions by onlap.

A major tectonic episode corresponding to normal faulting is closely associated with the boundary between Sequences K3 and P1; this event corresponds to the shift of the depocenter which moves from west (K1, K2, and K3) to east (P1, P2, PN1, and NQ1). Figure 12, which corresponds to a northeast-southwest transect of the Raggatt Basin (RS02-24), shows the seismic stratigraphic interpretation; Figure 13 shows a northwest-southeast transect (MD47-05) of the same basin.

The evolution of the Raggatt Basin, inferred from basin stratigraphy and based upon piston-core age determinations (Leclaire et al., 1987a, 1987b) can be summarized as follows (Schlich et al., 1988; Colwell et al., 1988; Coffin et al., in press):

1. The Southern Kerguelen Plateau basement was formed before Late Cretaceous time; it corresponds either to an oceanic-island-type structure or to excessive volcanism at, or near, the axis of an oceanic ridge.

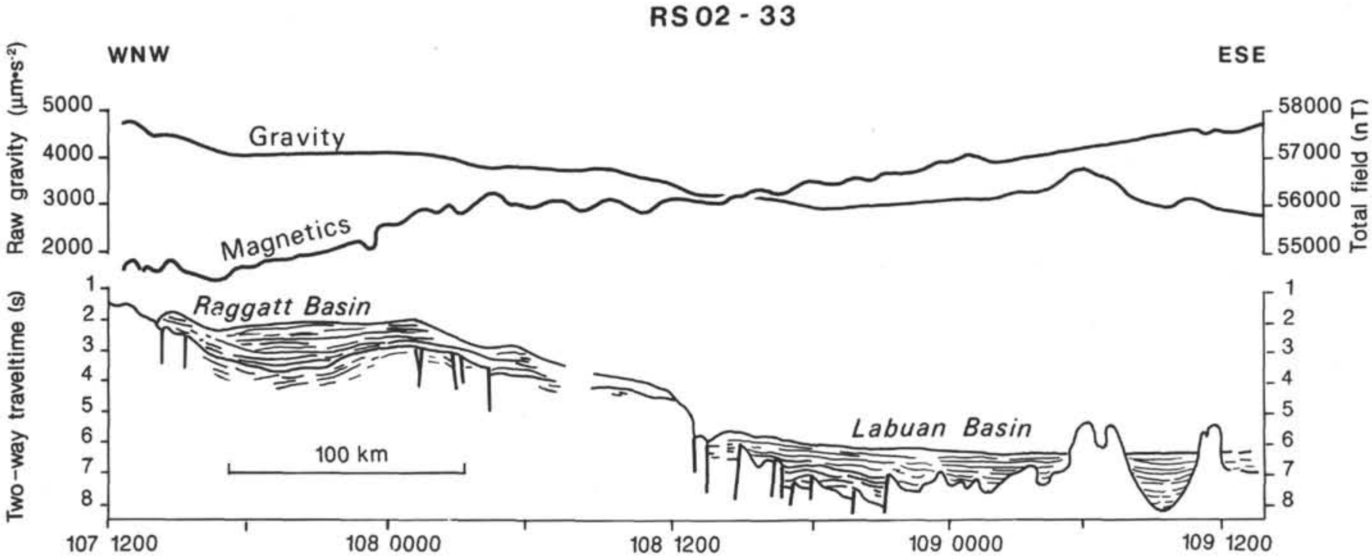

Figure 10. Line drawings across selected structural elements of the Southern Kerguelen Plateau (Ramsay et al., 1986). Gravity and magnetics profiles are also shown.

2. The top of the basement was eroded close to sea level (Fig. 13A).

3. During the Late Cretaceous, the sedimentary basin developed with local subsidence to form a trough that was progressively filled up by Sequences K1, K2, and K3. The lowermost sediments (Sequences K1 and possibly K2) are probably Cretaceous conglomerates and shelf limestones. Sequences K2 and K3 correspond probably to calcareous nannofossil ooze and chalk (Fig. 13B).

4. At the end of the Late Cretaceous, the western part of the basin was uplifted and normal faulting occurred. This event could mark the rifting between the Southern Kerguelen Plateau and the Diamantina Fracture Zone (Fig. 13C).

5. During the early Paleocene, Sequence P1 draped the newly shaped basin and normal faulting was almost continuous throughout this time interval (Fig. 13D).

6. From late Paleocene to Present, the Raggatt Basin continuously subsided and was progressively filled up with calcareous and siliceous oozes, probably interbedded with cherts, at least for the lowermost sequence (Sequences P2, PN1, and NQ1). Mounds affecting Sequences K3 and P1 developed during this time span (Fig. 13E).

DRILLING OBJECTIVES ON THE KERGUELEN PLATEAU

Deep-sea drilling to basement on the Kerguelen Plateau, as planned by 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:

1. the nature and age of the Kerguelen Plateau basement at sites located on identified structural elements (penetration into basement was 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; and
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.

Among the numerous locations that have been proposed for drilling (Proposals: PCOM #109C, #136C, #185C, and #273C), 14 specific sites and several alternates were considered by the different JOIDES panels. Finally, 7 sites complemented by 2 alternate sites were selected and accepted for drilling: 3 basement sites (SKP-1, SKP-4A, and SKP-6A), 2 Paleogene-Mesozoic stratigraphic and tectonic sites (KHP-3 and SKP-3B/SKP-3C), and 7 Neogene paleoceanographic sites including the 3 basement sites (KHP-1, SKP-1, SKP-2C, SKP-4A, SKP-6A, SKP-6B, SKP-8/SKP-8A).

All these sites are located on French and/or Australian multichannel seismic reflection lines and are shown in Figure 14. The coordinates and general characteristics of these sites are given in Table 1.

REFERENCES

Berggren, W. A., Kent, D. V., Flynn, J. J., and Van Couvering, J. A., 1985. Cenozoic geochronology. *Geol. Soc. Am. Bull.*, 96:1407–1418.

Bradley, L. M., and Frey, H., 1988. Constraints on the crustal nature and tectonic history of the Kerguelen Plateau from comparative magnetic modeling using MAGSAT data. *Tectonophysics*, 145:243–251.

Cande, S. C., and Mutter, J. C., 1982. A revised identification of the oldest sea-floor spreading anomalies between Australia and Antarctica. *Earth Planet. Sci. Lett.*, 58:151–160.

Coffin, M. F., Davies, H. L., and Haxby, W. F., 1986. Structure of the Kerguelen Plateau province from SEASAT altimetry and seismic reflection data. *Nature*, 324:134–136.

Coffin, M. F., Munschy, M., Colwell, J. B., Schlich, R., Davies, H. L., and Li, Z. G., in press. Seismic stratigraphy of the Raggatt Basin, Southern Kerguelen Plateau: tectonic and paleoceanographic implications. *Geol. Soc. Am. Bull.*

Colwell, J. B., Coffin, M. F., Pigram, C. J., Davies, H. L., Stagg, H.M.J., and Hill, P. J., 1988. Seismic stratigraphy and evolution of the Raggatt Basin, southern Kerguelen Plateau. *Mar. Pet. Geol.*, 5:75–81.

Dosso, L., Vidal, P., Cantagrel, J. M., Lameyre, J., Marot, A., and Zimine, S., 1979. Kerguelen: continental fragment or oceanic island?: petrology and isotopic geochemistry evidence. *Earth Planet. Sci. Lett.*, 43:46–60.

Fisher, R. L., Jantsch, M. Z., and Comer, R. L., 1982. *General Bathymetric Chart of the Oceans (GEBCO), Scale 1:10,000,000*: Ottawa (Canadian Hydrographic Service), 5.9.

Fröhlich, F., 1986. Presence de depots phosphates sur le plateau de Kerguelen-Heard (ocean Indien). *C. R. Acad. Sci., Ser. 2*, 303:167-170.

Fröhlich, F., Caulet, J. P., Clement, P., Fellah, N., Giannesini, P.-J., Wicquart, E., Averous, P., Blanc, G., Giannoni, A., Martin, L., Phillipot, F., and Prost, S., 1983. Mise en evidence d'une serie sedimentaire pélagique du Paléogène et du Crétacé Supérieur sur le plateau de Kerguelen. Résultats préliminaires de la campagne océanographique MD35 D.R.A.K.A.R. (mars 1983) du N.O. *Marion Dufresne. C. R. Acad. Sci., Ser. 2*, 297:153-156.

Giret, A., 1983. Le plutonisme oceanique intraplaque. Exemple de l'archipel des Kerguelen, Territoire des Terres Australes et Antarctiques Françaises [Ph.D. thesis]. Univ. P. et M. Curie, Paris, France.

Goslin, J., 1981. Etude geophysique des reliefs asismiques de l'ocean Indien occidental et austral [Ph.D. thesis]. Univ. Louis Pasteur, Strasbourg, France.

Guglielmi, M., 1982. Etude geophysique du plateau de Kerguelen [Diplome d'Ingenieur de l'Ecole et Observatoire de Physique du Globe]. Univ. Louis Pasteur, Strasbourg, France.

Hayes, D. E., and Vogel, M., 1981. *General Bathymetric Chart of the Oceans (GEBCO), Scale 1:10,000,000*: Ottawa (Canadian Hydrographic Service), 5.13.

Houtz, R. E., Hayes, D. E., and Markl, R. G., 1977. Kerguelen Plateau bathymetry, sediment distribution and crustal structure. *Mar. Geol.*, 25:95-130.

Kennett, J. P., 1978. The development of planktonic biogeography in the Southern Ocean during the Cenozoic. *Mar. Micropaleontol.*, 3: 301-345.

Leclaire, L., Bassias, Y., Denis-Clocchiatti, M., Davies, H., Gautier, I., Gensous, B., Giannesini, P.-J., Patriat, P., Segoufin, J., Tesson, M., and Wannesson, J., 1987a. Lower Cretaceous basalt and sediments from the Kerguelen Plateau. *Geo-Mar. Lett.*, 7:169-176.

Leclaire, L., Denis-Clocchiatti, M., Davies, H. L., Gautier, I., Gensous, B., Giannesini, P.-J., Morand, F., Patriat, P., Segoufin, J., Tesson, M., and Wannesson, J., 1987b. Nature et âge du plateau de Kerguelen-Heard, secteur sud. Résultats préliminaires de la campagne "N.A.S.K.A.-MD48". *C. R. Acad. Sci., Ser. 2*, 304:23-28.

Le Pichon, X., and Heirtzler, J. R., 1968. Magnetic anomalies in the Indian Ocean and sea-floor spreading. *J. Geophys. Res.*, 73:2101-2117.

Luyendyk, B. P., and Davies, T. A., 1974. Results of DSDP Leg 26 and the geologic history of the Southern Indian Ocean. *In* Davies, T. A., Luyendyk, B. P., et al., *Init. Repts. DSDP*, 26: Washington (U.S. Govt. Printing Office), 909-943.

McKenzie, D., and Sclater, J. G., 1971. The evolution of the Indian Ocean since the Late Cretaceous. *Geophys. J. R. Astron. Soc.*, 25: 437-528.

Mahoney, J. J., Macdougall, J. D., Lugmair, G. W., and Gopalan, K., 1983. Kerguelen hotspot source for Rajmahal Traps and Ninetyeast Ridge? *Nature*, 303:385-389.

Munschy, M., and Schlich, R., 1987. Structure and evolution of the Kerguelen-Heard Plateau (Indian Ocean) deduced from seismic stratigraphy studies. *Mar. Geol.*, 76:131-152.

Mutter, J. C., and Cande, S. C., 1983. The early opening between Broken Ridge and Kerguelen Plateau. *Earth Planet. Sci. Lett.*, 65:369-376.

Mutter, J. C., Hegarty, K. A., Cande, S. C., and Weissel, J. K., 1985. Breakup between Australia and Antarctica: a brief review in the light of new data. *Tectonophysics*, 114:255-279.

Quilty, P. G., 1973. Cenomanian-Turonian and Neogene sediments from northeast of Kerguelen Ridge, Indian Ocean. *J. Geol. Soc. Aust.*, 20:361-371.

Ramsay, D. C., Colwell, J. B., Coffin, M. F., Davies, H. L., Hill, P. J., Pigram, C. J., and Stagg, H.M.J., 1986. New findings from the Kerguelen Plateau. *Geology*, 14:589-593.

Recq, M., and Charvis, P., 1986. A seismic refraction survey in the Kerguelen isles, Southern Indian Ocean. *Geophys. J. R. Astron. Soc.*, 84:529-559.

———, 1987. La ride asismique de Kerguelen-Heard. Anomalie du geoide et compensation isostatique. *Mar. Geol.*, 76:301-311.

Recq, M., Charvis, P., and Hirn, A., 1983. Preliminary results on the deep structure of the Kerguelen Ridge, from seismic refraction experiments. *C. R. Acad. Sci., Ser. 2*, 297:903-908.

Schlich, R., 1975. Structure et âge de l'océan Indien occidental. *Mem. Hors-Ser. Soc. Geol. Fr.*, 6:1-103.

———, 1982. The Indian Ocean: aseismic ridges, spreading centers, and oceanic basins. *In* Nairn, A.E.M., and Stehli, F. G. (Eds.), *The Ocean Basins and Margins: The Indian Ocean* (Vol. 6): New York (Plenum), 51-147.

Schlich, R., and Patriat, P., 1967. Profils magnetiques sur la dorsale medio-oceanique "Indo-Pacifique." *Ann. Geophys.*, 23:629-633.

———, 1971a. Mise en evidence d'anomalies magnetiques axiales sur la branche ouest de la dorsale medio-indienne. *C. R. Acad. Sci., Ser. 2*, 272:700-703.

———, 1971b. Anomalies magnetiques de la branche est de la dorsale medio-indienne entre les iles Amsterdam et Kerguelen. *C. R. Acad. Sci., Ser. 2*, 272:773-776.

Schlich, R., Delteil, J., Moulin, J., Patriat, P., and Guillaume, R., 1971. Mise en évidence d'une sédimentation de marge continentale sur le plateau de Kerguelen-Heard. *C. R. Acad. Sci., Ser. 2*, 272: 2060-2063.

Schlich, R., Coffin, M. F., Munschy, M., Stagg, H.M.J., Li, Z. G., and Revill, K., 1987. *Bathymetric Chart of the Kerguelen Plateau.* [Jointly edited by Bureau of Mineral Resources, Geology and Geophysics, Canberra, Australia, Institut de Physique du Globe, Strasbourg, France, and Territoire des Terres Australes et Antarctiques Françaises, Paris, France.]

Schlich, R., Munschy, M., Boulanger, D., Cantin, B., Coffin, M. F., Durand, J., Humler, E., Li, Z. G., Savary, J., Schaming, M., and Tissot, J. D., 1988. Résultats préliminaires de la campagne océanographique de sismique reflexion multitraces MD47 dans le domaine sud du plateau de Kerguelen. *C. R. Acad. Sci., Ser. 2*, 305:635-642.

Wicquart, E., 1983. Modele lithostratigraphique du plateau de Kerguelen-Heard, ocean Indien [These de troisieme cycle]. Univ. P. et M. Curie, Paris, France.

Wicquart, E., and Fröhlich, F., 1986. La sedimentation sur le plateau de Kerguelen-Heard: relations avec l'evolution de l'ocean Indien au Cenozoique. *Bull. Soc. Geol. Fr.*, 8:569-574.

Ms 120A-102

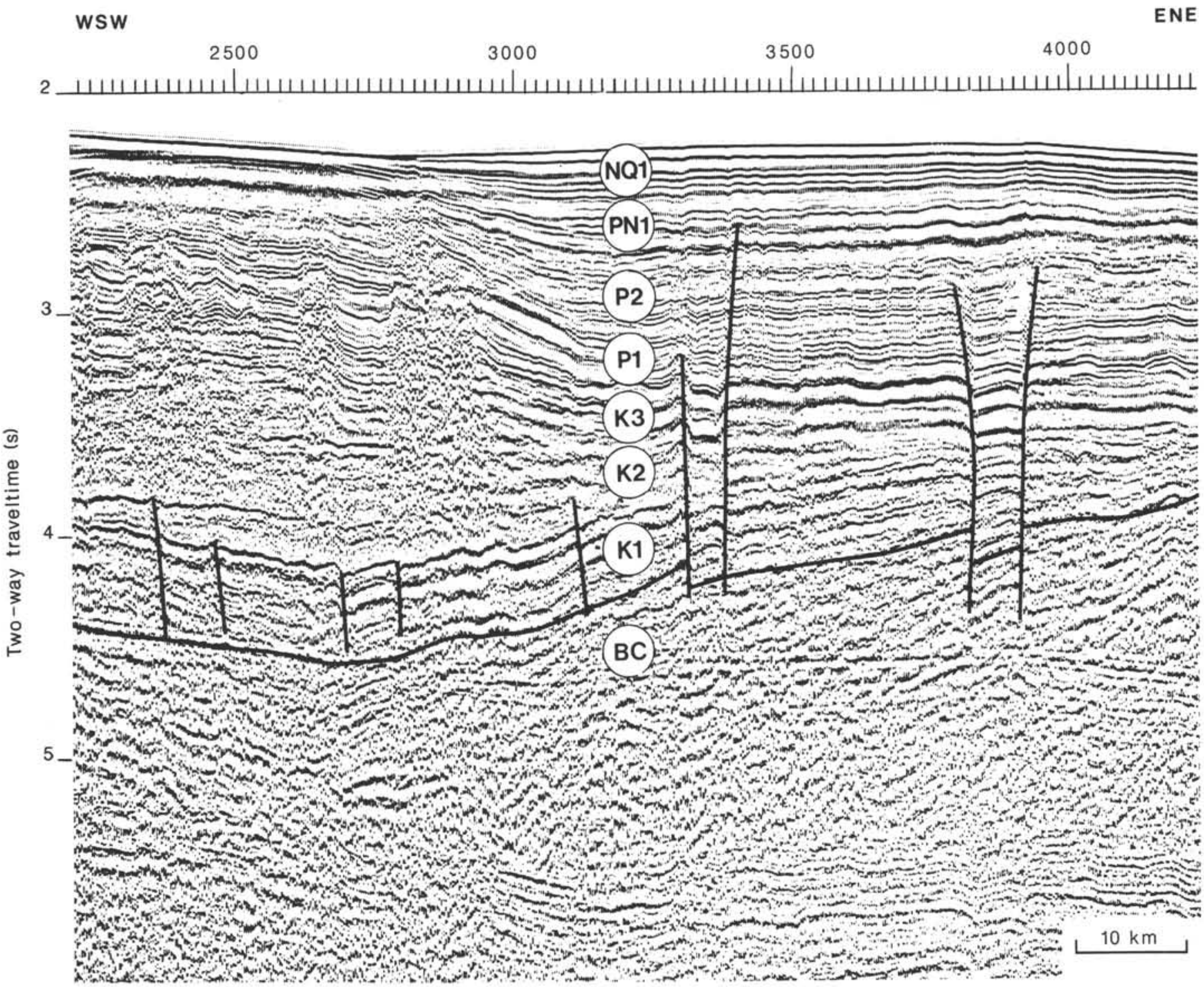

Figure 11. Northeast-southwest transect (RS02-24) of the Raggatt Basin on the Southern Kerguelen Plateau (Coffin et al., in press). The seismic sequence identified by Schlich et al. (1988) and Colwell et al. (1988) are shown in the figure and are discussed in the text.

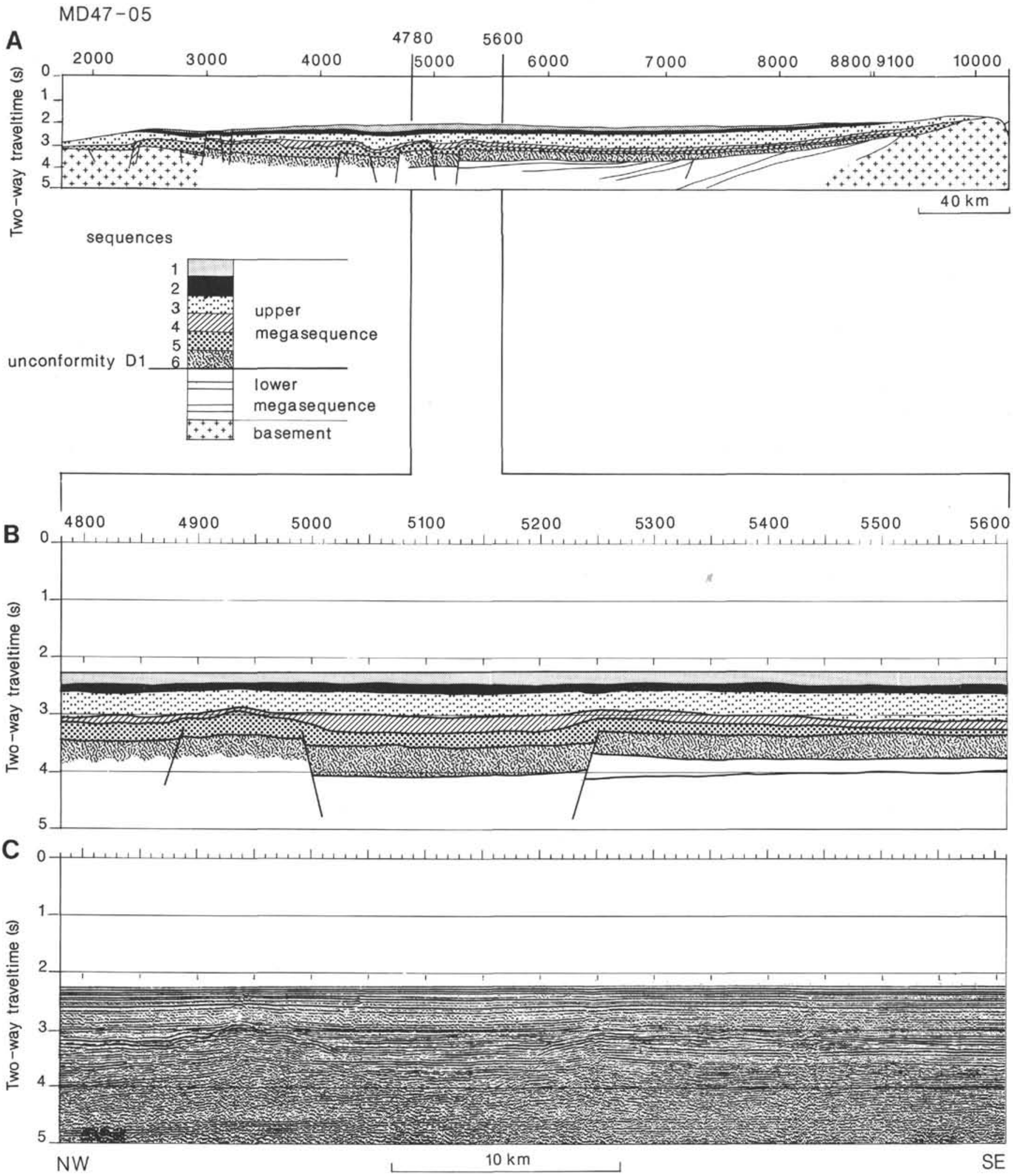

Figure 12. Northwest-southeast transect (MD47-05) of the Raggatt Basin on the Southern Kerguelen Plateau (Schlich et al., 1988). **A.** Interpreted cross section. **B.** Detail of the interpreted section from 4780 to 5600. **C.** Uninterpreted section.

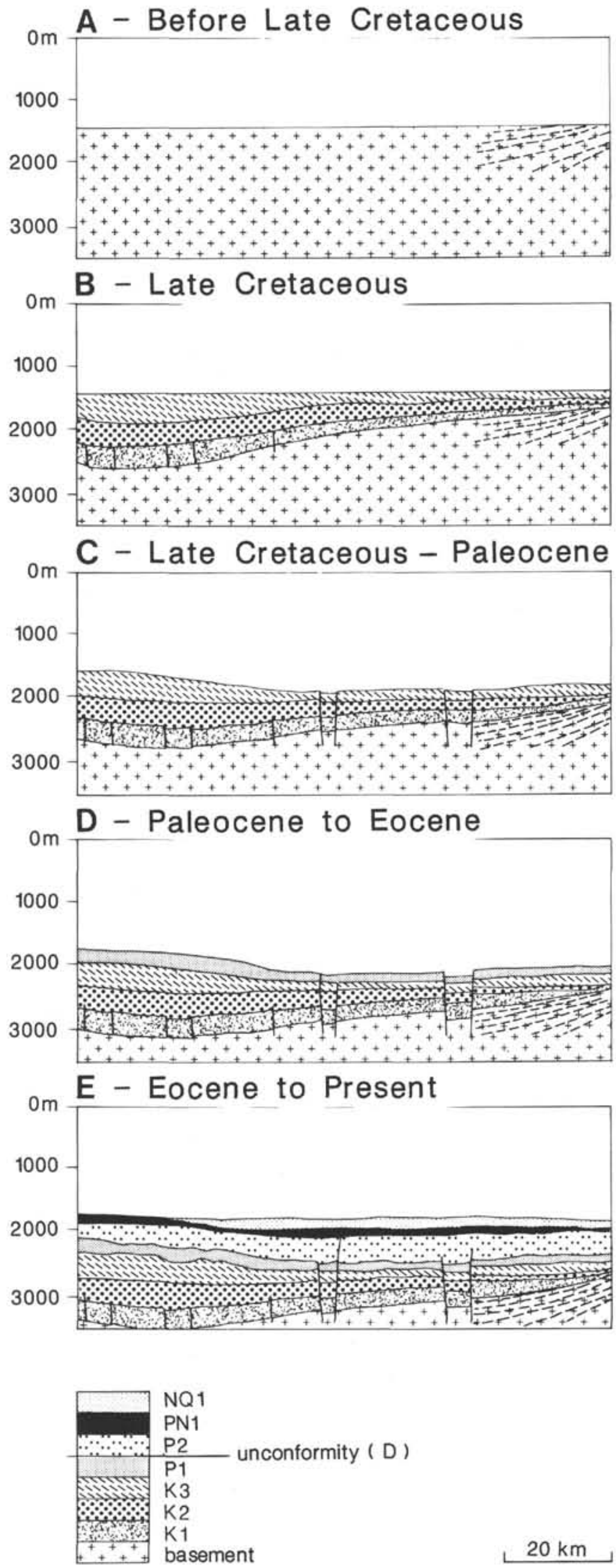

Figure 13. Schematic representation of the evolution of the Raggatt Basin on the Southern Kerguelen Plateau from Cretaceous to Holocene time.

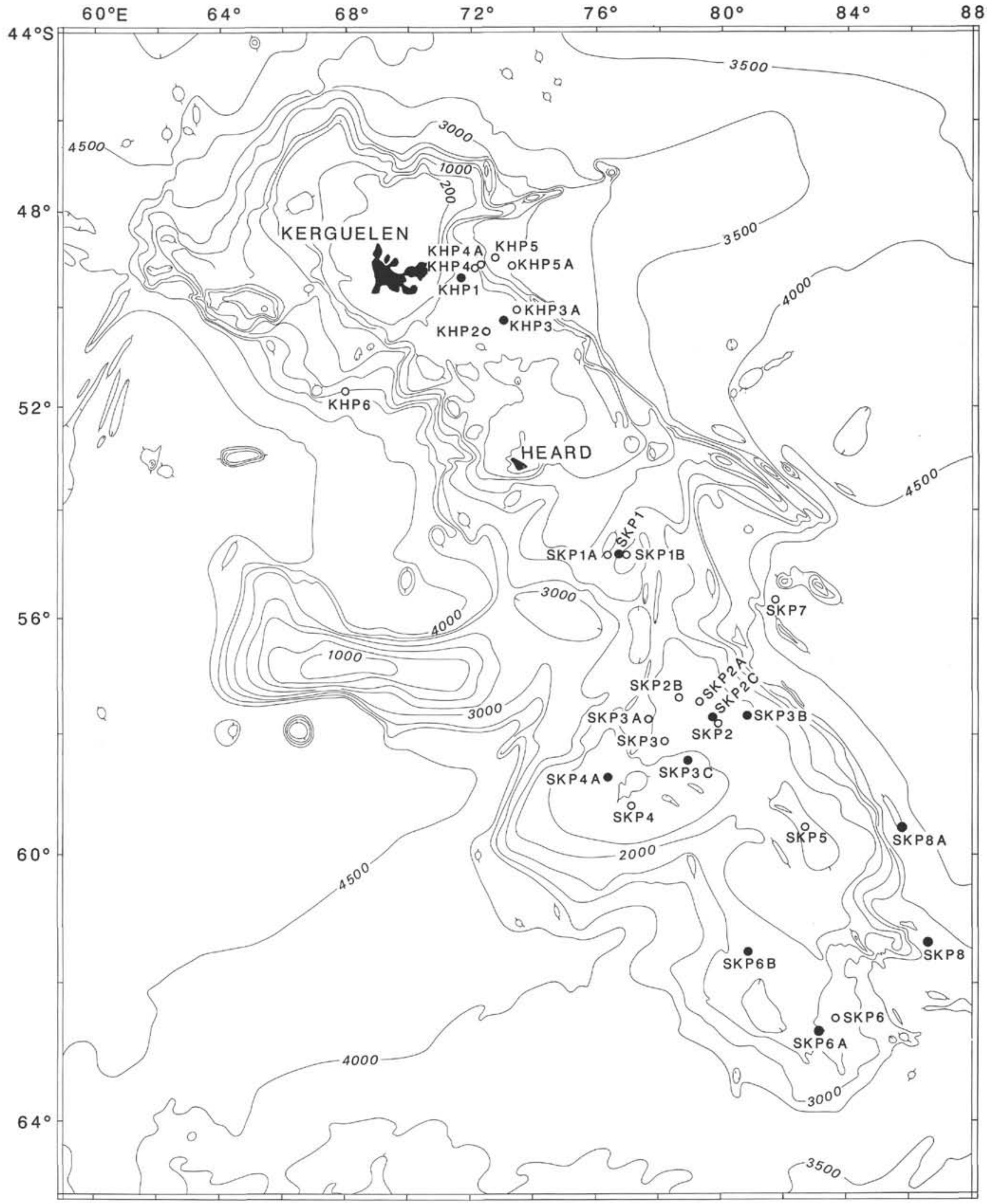

Figure 14. Location of the drilling sites on the Kerguelen Plateau (Leg 119 and 120 sites). Bathymetry in meters. Open circles represent IPG-BMR sites, and closed circles, selected sites.

Table 1. Proposed drilling sites on the Kerguelen Plateau: Location on seismic multichannel reflection profiles, coordinates, water depth, and sediment thickness.

Site	Profile	Date	Time	Shot-point	Location	Water depth (m)	Sediment thickness (m)	Total penetration (m)
KHP1	MD26-10	5 Apr	1958	2300	49°23.6′S, 71°39.5′E	660	3170	910
KHP2	MD26-07	31 Mar	1202	3180	50°29.0′S, 72°29.4′E	570	2310	1210
KHP2	MD26-04	24 Mar	1552	3670	50°29.0′S, 72°29.4′E	570	2310	1210
KHP3	MD26-07	31 Mar	1628	4120	50°14.2′S, 73°02.5′E	570	1670	1700
KHP3	MD26-13	13 Apr	1937	1630	50°14.2′S, 73°02.5′E	570	1670	1700
KHP3A	MD26-07	31 Mar	2010	4900	50°01.5′S, 73°31.5′E	750	1500	1530
KHP4	MD26-10	6 Apr	0436	5100	49°12.2′S, 72°01.4′E	820	1340	1370
KHP4A	MD26-10	6 Apr	0516	5240	49°10.6′S, 72°06.6′E	990	710	740
KHP5	MD26-10	6 Apr	1056	6390	48°56.9′S, 72°46.3′E	2310	1810	1840
KHP5A	MD26-11	7 Apr	1716	990	49°02.9′S, 73°28.3′E	2450	1930	1960
KHP6	GA03-21	18 Feb	0603	8600	51°50.0′S, 68°00.0′E	3390	910	940
SKP1	MD47-03	15 Jan	1559	11400	54°48.8′S, 76°47.4′E	1700	400	450
SKP1	RS02-13	28 Mar	2115	—	54°48.8′S, 76°47.4′E	1700	400	450
SKP1A	MD47-03	15 Jan	1431	11050	54°49.1′S, 76°31.2′E	1540	800	850
SKP1B	MD47-03	15 Jan	1623	11500	54°48.8′S, 76°51.8′E	1780	300	350
SKP2	MD47-05	17 Jan	0621	5838	57°48.9′S, 79°55.8′E	1660	3500	?1000–1300
SKP2	RS02-24	7 Apr	1354	—	57°48.9′S, 79°55.8′E	1660	3500	?1000–1300
SKP2A	RS02-22	6 Apr	0217	—	57°26.4′S, 79°17.2′E	1710	?	1100–1500
SKP2B	MD47-14	30 Jan	1432	4410	57°20.6′S, 78°44.2′E	1690	?	900–1200
SKP2C	MD47-05	17 Jan	0519	5600	57°43.6′S, 79°49.0′E	1660	>3000	390–1000
SKP3	RS02-24	7 Apr	0415	—	58°07.6′S, 78°11.4′E	1500	1300?	1300+
SKP3A	RS02-22	6 Apr	1049	—	57°42.2′S, 77°51.0′E	1950	1300?	1300+
SKP3B	RS02-24	7 Apr	1950	—	57°39.2′S, 80°58.6′E	1900	1050	1100+
SKP3C	RS02-27	10 Apr	2340	—	58°26.3′S, 78°59.2′E	1300	1290	1340+
SKP4	MD47-13	28 Jan	1227	4331	59°12.0′S, 77°06.7′E	1260	900	950
SKP4	RS02-29	14 Apr	1739	—	59°12.0′S, 77°06.7′E	1260	900	950
SKP4A	MD47-13	28 Jan	1930	5670	58°43.0′S, 76°24.4′E	1160	300	350
SKP5	MD47-05	18 Jan	0618	11250	59°34.5′S, 82°43.0′E	1350	600	650
SKP6	MD47-08	20 Jan	0800	855	62°30.0′S, 83°40.2′E	2610	1300	1350
SKP6	ND34	17 Jan	1730	—	62°30.0′S, 83°40.2′E	2610	1300	1350
SKP6A	MD47-08	20 Jan	0426	50	62°44.0′S, 83°05.2′E	2360	500	550
SKP6B	MD47-07	19 Jan	1231	608	61°31.4′S, 80°52.1′E	2260	900	1000
SKP7	RS02-15	31 Mar	1840	—	55°38.6′S, 81°47.8′E	4600	900	450–740
SKP8	MD47-08	21 Jan	0258	5120	61°17.8′S, 86°46.7′E	3850	1000	700
SKP8A	MD47-10	25 Jan	2300	8110	59°32.0′S, 85°49.5′E	4090	1000	600

Note: MD = *Marion Dufresne*, RS = *Rig Seismic*, GA = *Gallieni*, and ND = *Nella Dan*.