OCEAN DRILLING PROGRAM

LEG 135 SCIENTIFIC PROSPECTUS

Lau Basin

Dr. James Hawkins
Co-Chief Scientist, Leg 135
Scripps Institution of Oceanography
M/S A-020
University of California at San Diego
La Jolla, CA 92093

Dr. Lindsay Parson
Co-Chief Scientist, Leg 135
Institute of Oceanographic Sciences
Brook Road, Wormley
Godalming, Surrey GU8 5UB
United Kingdom

Dr. James Allan
Staff Scientist, Leg 135
Ocean Drilling Program
Texas A&M University
College Station, Texas 77845-9547

Philip D. Rabinowitz
Director
ODP/TAMU

Audrey W. Meyer
Manager
Science Operations
ODP/TAMU

Timothy J.G. Francis
Deputy Director
ODP/TAMU

September 1990

Scientific Prospectus No. 35
First Printing 1990

Distribution

Copies of this publication may be obtained from the Director, Ocean Drilling Program, Texas A&M University Research Park, 1000 Discovery Drive, College Station, Texas 77845-9547. In some cases, orders for copies may require payment for postage and handling.

## DISCLAIMER

This publication was prepared by the Ocean Drilling Program, Texas A&M University, as an account of work performed under the international Ocean Drilling Program, which is managed by Joint Oceanographic Institutions, Inc., under contract with the National Science Foundation. Funding for the program is provided by the following agencies:

Canada/Australia Consortium for the Ocean Drilling Program
Deutsche Forschungsgemeinschaft (Federal Republic of Germany)
Institut Français de Recherche pour l'Exploitation de la Mer (France)
Ocean Research Institute of the University of Tokyo (Japan)
National Science Foundation (United States)
Natural Environment Research Council (United Kingdom)
European Science Foundation Consortium for the Ocean Drilling Program (Belgium, Denmark, Finland, Iceland, Italy, Greece, the Netherlands, Norway, Spain, Sweden, Switzerland, and Turkey)

Any opinions, findings and conclusions or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the National Science Foundation, the participating agencies, Joint Oceanographic Institutions, Inc., Texas A&M University, or Texas A&M Research Foundation.

This Scientific Prospectus is based on pre-cruise site-survey information and JOIDES panel discussions. The operational plans within reflect JOIDES Planning Committee and thematic panel priorities. During the course of the cruise, actual site operations may indicate to the Co-Chief Scientists and the Operations Superintendent that it would be scientifically advantageous to amend the plan detailed in this prospectus. It should be understood that any proposed changes to the plan presented here are contingent upon approval of the Director of the Ocean Drilling Program in consultation with the Planning Committee and the Pollution Prevention and Safety Panel.

## ABSTRACT

The objective for ODP Leg 135 is to understand the geologic history of the Lau Basin. A drilling transect with five sites is planned. One site will sample old backarc crust in the western Lau Basin, two sites will sample young crust in the central basin, one site will be drilled on the Tonga platform, and a fifth site will sample the outer edge of the Tonga forearc.

The transect will address one of the thematic problems posed in the COSOD I science plan. This question, concerning the temporal relationships between arc volcanism, subduction processes (e.g., accretion vs. non-accretion), and backarc extension and compression, will be explored within the Lau Basin-Tonga arc system.

## INTRODUCTION

The objective for Leg 135 is to deduce the geologic history of the Lau Basin. The results will be important, not only for understanding the evolution of the Lau Basin, but for gaining a better understanding of the geologic processes that form new oceanic crust at convergent plate margins. In addition to adding to our knowledge of Lau Basin-Tonga arc and forearc geology, a major goal is to assess the links between backarc spreading, island-arc volcanism, and subduction. We will address the temporal relationships between arc volcanism, subduction processes (e.g. accretion vs. non-accretion), and backarc extension and compression. This problem was identified as a major thematic objective in the COSOD I science plan (JOI, 1981). It was reiterated in the COSOD II plan, which perceived a need for "clearer documentation of the interaction between such (arc and backarc) magma types both spatially and with time in the development of an arc-backarc system" (JOI-ESF, 1987). The Lau Basin was selected because (1) it has been the target of numerous marine geologic and geophysical studies including a deep drill hole (DSDP Site 203; Burns, Andrews, et al., 1973), (2) the geology of the nearby Lau and Tonga arcs is well known, and (3) we have some testable models for its evolution. A drilling transect of five sites (Fig. 1) is planned that will sample the backarc-basin crust and the arc-forearc area of the Tonga Ridge. The Lau Basin studies will complement parallel studies of the Mariana Arc-Trough and Bonin Arc areas; collectively the results should help to improve our models for backarc-basin evolution.

The Lau Basin (Fig. 1) has formed by the emplacement and eruption of basaltic magmas within rifts and as seamounts in a region of lithospheric extension between the Lau Ridge and the Tonga Trench. The age of inception of this extension is poorly constrained by magnetic anomaly data but has been variously interpreted as about 2.5 to 3 Ma. The rate of opening probably varies with latitude; near 18°S, where the magnetic data are better constrained, the spreading rate may be 5-6 cm/yr in an east-west direction. It is clear that crustal generation by seafloor spreading has operated in the basin since late Pliocene time.

It is also well established that the modern volcanic arc (Tofua Arc) has been active since at least early to mid-Pleistocene time (~1 Ma), and that parts of the forearc basement include pre-late Eocene gabbro and basaltic rocks as well as younger arc-volcanic rocks. The age of initial volcanism of the Tofua Arc has not been determined, although some have proposed that it represents a direct continuation of Lau Ridge volcanism which lasted until about 3 Ma. Alternatively, the data may be interpreted as indicating a hiatus in arc volcanism that resulted in the modern (Tofua Arc) volcanoes being new volcanic-plutonic systems imprinted on what was formerly the forearc region of the Lau Ridge. This major question of Tofua Arc genesis will be addressed by the drilling plan.

The Lau Basin appears to be spreading actively and has a well-defined axial ridge system near 176°30'W between latitudes 17°S and 22°S (Fig. 1). The axial ridge is formed of relatively unfractionated olivine tholeiite basalt, but more fractionated and Fe-Ti-enriched lavas are found near a propagating rift tip at 19°30'S. The extreme southern end of this axial ridge (Valu Fa Ridge) differs markedly from the rest of the basin in being dominated by rocks of andesitic to dacitic composition. This part of the axial ridge has abundant hydrothermal vents, and seismic data have been interpreted as indicating the presence of a magma chamber. The basin is much more complex north of 17°S and east of 178°W: here there are abundant seamounts, including the volcanically active island Niua Fo'ou; a nascent triple junction having one limb that intersects the Tofua Arc and a western limb that projects toward Niua Fo'ou; and a well- defined ridge which presently marks the trend of a zone of right-lateral strike-slip as defined by first-motion studies of shallow seismic activity (Peggy Ridge).

The Lau Basin presents a number of important problems concerning the tectonic/petrologic evolution of the lithosphere above the plate-convergence system of the Tonga Trench subduction zone. In addition to giving insights into how backarc basins evolve, it also offers an opportunity to understand broader problems of crustal evolution that pertain to other intra-oceanic trench-forearc-backarc systems. The proposed drilling transect of 5 sites will include studies of both the earliest crust formed as the basin opened and the crust rifted away from the remnant arc (Lau Ridge) and now exposed on the forearc, which pre-date backarc opening.

## REGIONAL SETTING - LAU BASIN

The Lau Basin (Fig. 1) separates the Lau Ridge (remnant arc) from the Tonga Ridge. The Tonga Ridge comprises two parallel chains of islands and shoals that cap the older seafloor on the inboard side of the Tonga Trench. The western chain includes active volcanic islands of the Tofua Arc which have erupted basaltic andesite to low-K rhyolitic magmas (Ewart and Bryan, 1972; Ewart et al., 1973). The eastern chain consists of tilted blocks formed of upper Eocene to Pleistocene limestone with interbedded tuffs and volcaniclastic beds which overlie an igneous basement comprising mafic plutonic rocks, basaltic to andesitic pillow lavas, dikes and aa flows. Ewart and Bryan (1972) proposed that the rocks of 'Eua constitute the upper part of an ophiolite assemblage. The oldest rocks of the region are the Eocene (46 Ma) "crystalline basement" of 'Eua, known from boulders of gabbro, norite, basalt, andesite, dacite, and rhyolite (Cunningham and Anscome, 1985). The chemistry of these rocks is typical of an island arc volcanic-plutonic series (Ewart and Bryan, 1972; Cunningham and Anscome, 1985). The lowest outcrops exposed in the 'Eua section are basaltic to andesitic flow and dikes (Hawkins and Falvey, 1985). These are overlain by upper Eocene to lower Oligocene limestone (Cole, 1970) and in turn, these are overlain by a series of Miocene to Pliocene volcaniclastic rocks that are interbedded with foraminiferal limestone (Cunningham and Anscome, 1985). Three distinct episodes of Tertiary volcanic activity are recognized on 'Eua by Duncan et al. (1985). The oldest, 40-46 Ma, is measured on the gabbro and basalt beach boulders; basaltic and andesitic flows give ages of 31-33 Ma, and andesitic dikes give 17-19 Ma ages. Paleontologic ages of tuffaceous sediments range from middle Miocene to early Pliocene, i.e., until 3-5 Ma.

The islands of the Lau Ridge display a more complete record of early Tertiary volcanism than is exposed on the uplifted blocks of the Tonga Ridge. The oldest rocks known are the middle to upper Miocene Lau Volcanic Group (6-14 Ma), which are mainly basalt and basaltic andesite but also include andesite, dacite, and rhyolite. This group consists mainly of low- to medium-K arc tholeiitic and calc-alkaline series lavas (Woodhall, 1985; Cole et al., 1985) and is interpreted as representing the early and mature stages of arc evolution. Some of the Oligocene and Miocene rocks of the Tonga Ridge probably are correlative with the Lau Ridge volcanism even though no Oligocene rocks are known from the Lau Ridge. It is likely that the Lau Ridge first became active in Eocene time, based on other occurrences of Eocene volcanic series in the broader Fiji-Tonga area.

Lau Ridge volcanism ended in the late Miocene and was followed by erosion, subsidence, and the growth of coral reefs. Renewed volcanism, forming the Korobasage Volcanic Group (4-3 Ma), may have been in response to the initial phase of rifting that led to the opening of the Lau Basin (Cole et al., 1985). The Korobasage Group is formed mainly of submarine tholeiitic basalt but also includes some hornblende andesite. The youngest Lau Ridge volcanism is represented by the Mago Volcanic Group (<2.5 Ma), which includes alkalic olivine basalt and hawaiite. The eruption of these lavas may have been coeval with, or slightly older than, the earliest phases of Lau Basin opening.

The geologic record seen on the Tonga and Lau ridges demonstrates the transition from plate convergence accompanied by arc volcanism (Eocene? to late Miocene) to cessation of arc volcanism and submergence of the arc (late Miocene). This was followed by rifting of the arc and renewed arc and submarine volcanic activity (early Pliocene). Backarc basin rifting probably began in the late Pliocene (2.5 Ma), e.g., at the time of magnetic anomaly 2a, which has been recognized in the western Lau Basin (Malahoff et al., 1982). The fabric of the Lau Basin has proved difficult to determine and, although the major elements of the geometry were recognized some time ago (e.g., Hawkins, 1974; Lawver et al., 1976), the use of GLORIA imagery coupled with SeaBeam and magnetics data from PAPATUA and ROUNDABOUT expeditions has enabled Parson et al. (1990) to greatly improve our understanding of the Lau Basin tectonic fabric. The time of beginning of volcanism on the Tofua Arc remains a major question that may be resolved in the ODP Leg 135 drilling transect in the Lau Basin. Hawkins and Melchior (1985) proposed that the Tofua Arc did not become active until mid- to late-Pleistocene time, and this accounts for the lack of volcanic detritus in the Pleistocene and younger limestones of the Tonga Ridge (Stearns, 1971). An alternate view, long favored, is that the active volcanic arc was rifted away from the Lau Ridge and implies that the modern Tofua Arc is a direct petrogenetic descendant of the Lau Ridge.

These two possible models for post-late Miocene Lau Basin evolution are shown in Figure 2. The pre-late Miocene history (Fig. 2A) is complex, and we show an island-arc system related to west-dipping subduction. In fact, the Lau Ridge - Fiji Islands may represent more than one arc complex; there may have been subduction reversals or amalgamation of arc terranes, but this history is not important for this discussion.

The original model (Karig, 1970) proposed that the Lau Ridge arc system split (Fig. 2B), with the Lau Basin subsequently forming in the rifted area. A consequence of this style of evolution would be that arc volcanism in the Tofua Arc is a direct continuation of Lau Ridge volcanism. The area encompassing the former forearc to the Lau Ridge (except what has been removed by tectonic erosion) has moved eastward relative to the Lau Ridge. The more recent model (Hawkins et al., 1984; Hawkins and Melchior, 1985; Fig. 2C) proposes that the rifting to form the Lau Basin was initiated in the forearc instead of within the Lau Ridge volcanic arc. In this case, the modern Tofua Arc is a new volcanic system built either on the Lau Ridge forearc or on an older part of the current backarc basin. This model suggests that some fragments of forearc crust may have been left under the western Lau Basin. The presence or extent of this forearc material would depend on how close the rifts formed to the Lau Ridge.

The crust of the Lau Basin is floored mainly by basalt, which has most of the mineralogic, chemical and isotopic characteristics of mid-ocean ridge basalt (MORB) and includes varieties termed "normal" (N-MORB) and "enriched" (E-MORB). The least altered, least fractionated, basalt glasses of the neo-volcanic zones of the axial ridges generally have this N-MORB signature, with the notable exception that $^{87}Sr/^{86}Sr$ is more radiogenic than N-MORB (e.g., 0.7035 or higher), but otherwise element ratios and abundances are clearly MORB-like, rather than like arc lavas. Rocks and glasses collected from the outer (older) edges of the Lau Basin are variable in composition, and many show "arc-like" characteristics. This suggests that there is an age-dependent magmatic variation from initial arc-like or transitional to arc composition to more MORB-like compositions (Hawkins, 1976; Hawkins and Melchior, 1985; Sinton et al., 1985; Volpe et al., 1988).

The data are interpreted as indicating that the Lau Basin, as well as other backarc basins, have undergone a petrologic evolution from basaltic melts having a strong imprint, or memory, of an arc source (or arc-like melt component) to basalts that have a strong N-MORB signature. In the evolutionary process there are many petrological diversions that may be unique to certain basins, e.g., the formation of extensive eruptions of "high silica" (56-62% $SiO_2$) lavas such as those of the Valu Fa Ridge in the Lau Basin (von Stackelberg et al., 1985; Vallier et al., in press; Nautilau, 1990). A further complexity in the Lau Basin is the development of the northern seamount province, which has an E-MORB or "plume" signature (Poreda, 1985; Volpe et al., 1988). Our interpretation of Lau Basin history, from the Leg 135 cores, will be guided by these observations.

The Lau Basin data show that the mantle sources are quite heterogeneous in a three-dimensional view and that these heterogeneities may have persisted or have been reinstated on the short time span (<5 m.y.) associated with its opening. One of the objectives of the drilling transect will be to sample backarc crust at 3 (or 4 if time permits) sites of different age to look for compositional variability and to compare the older crust with samples from the neo-volcanic zone. The Lau Basin and other backarc basins are important geologic features in their own right, but an understanding of their geology has two important implications for understanding crustal evolution. They may offer insight to the earliest stages of the tectonic/petrologic processes that form mid-ocean ridges; the evidence for these stages is usually long since buried by seafloor sediments. A second implication is related to the origin of ophiolites and the ophiolite model for the nature of oceanic lithosphere. There is a growing consensus that many, if not most, ophiolite suites originally formed in arc/backarc settings (e.g., Dewey and Bird, 1971; Hawkins, 1976; Hawkins et al., 1984). A proper understanding of the range in chemistry and petrology of backarc-basin lavas is necessary for evaluating the origin of ophiolite series and their relevance to models for ocean crust formed at mid-ocean-ridge settings.

## DRILLING OBJECTIVES

The drilling plan for the Lau Basin (Fig. 1) will collect data on a transect across the basin from the presumed oldest crust on the west to younger crust near the presently active axial ridge. It also will sample the crust of the Tonga platform and forearc. No sites are planned for the axial rift zone or the Valu Fa Ridge because of the difficulties with drilling at a bare-rock setting and because of potential problems with high-temperature environments. Three sites (LG-2, LG-7, and LG-10) are planned for the backarc basin; five sites (LG-1, LG-1A, LG-9, LG-9A, and LG-10A) are planned as contingency sites in the event that any of the primary sites in the backarc basin have to be abandoned. The forearc/upper-trench slope will be the target of site LG-6A and the Tonga platform will be drilled at site LG-3.

Detailed site surveys have been undertaken in the vicinity of all of the proposed sites to ensure that (a) sampling objectives will be achieved with suitable drilling conditions and (b) the requirements of the JOIDES Safety Panel (PPSP) were fully met. Site survey information gathered at each of the proposed sites is discussed in the following text.

Site locations are shown in Figure 1. A summary of the primary and alternate sites is given in Table 1. Time estimates for transits and for planned site operations are given in Table 2.

## Backarc Basin Transect

Primary sites proposed for the backarc basin transect include LG-2, LG-7, and LG-10. Collectively the backarc transect sites, plus the work already done at the neo-volcanic zone, will give us an understanding of the physical and chemical/petrologic properties of backarc crust formed over the last ~3 m.y., from several different mantle sources, and from the initial stages of rifting to the present. Major objectives for drilling in the backarc basin include the following:

1. Determining the age and composition of the basement.
2. Recording the stratigraphy, sedimentary petrology, geochemistry, and paleontologic record of the sedimentary column.
3. Understanding the diagenetic history of the sediments.
4. Documenting the fluid geochemistry and physical properties of the sediments and basement.
5. Investigating the nature and origin of metalliferous deposits in the crystalline basement, basal sediments, and sediment column.
6. Assembling a chronology of rifting, arc volcanism, and variations in backarc basin crustal composition.

At the backarc basin sites we expect to drill calcareous oozes interbedded with volcanic ash and clastic volcanic material. Basement is likely to be basalt.

### *LG-2*

Site LG-2 is planned to penetrate 300 m of sediment and 200 m of basement. The site is in a small, steep-sided basin that trends north-south along the western side of the Lau Basin close to the Lau Ridge. Located in the most easterly part of the central backarc basin, the site was the target in 1988 and 1989 of single-channel seismic profiling during *Charles Darwin* cruise 33 (CD33), and the ROUNDABOUT 14 cruise aboard *Thomas Washington* (RNDB14). The requirement to locate the site within deep sedimented basins less than 5 km wide that separate emergent north-south basement ridges meant closely spaced track lines. Regional GLORIA long-range sidescan sonar, coupled with SeaBeam swath bathymetric data allowed sites to be positioned away from highly reflective areas of seafloor (neo-volcanics?; pumice fields?). Despite processing and analysis of the seismic data, resolution of coherent reflectors below a high-amplitude unit (at ~200-300 mbsf) is not possible. Some uncertainty exists as to the rock types that will be encountered at depth, either backarc extrusives or forearc complex. Mass-wasted material derived from adjacent ridges could prove a challenge for drilling operations.

*LG-7*

Site LG-7 is located in a small north-south-trending basin ~60 km east of LG-2. The drill hole is planned to penetrate ~100 m of sediment and 50 m (or to bit destruction, whichever is deeper) of basement. An intermediate-age backarc site, LG-7 was sited in a north-south sedimented basin flanked by scarps and draped upstanding basement ridges, using a CD33 profile flanked by additional CD and RNDB14 data, and GLORIA and SeaBeam sonars.

*LG-10*

Site LG-10 (and contingency site LG-10A) is located in the central Lau Basin on crust estimated to be less than 1 Ma. A sediment thickness of ~100 m and 200 m of basement will be cored. As with site LG-9, LG-10 has been surveyed with a combination of single-channel seismic data from CD33 and RNDB14 cruises, as well as GLORIA and SeaBeam. With 100 m of sediment or less overlying basement, the site is considered to be the youngest backarc site that could be selected for drilling without the requirement of setting a bare-rock guidebase. Sub-bottom reflectors are difficult to trace unequivocally, due to bubble-pulse interference in the upper 0.2 seconds two-way traveltime (s TWT) of the seismic record. Local planar subsurface events, however, coupled with sonar data interpretations, identify sediment pockets of sufficient size to locate LG-10 (this is also the case at contingency sites LG-9, LG-9A, LG-10A, LG-1, and LG-1A).

## Tonga Platform and Forearc

The overall objectives for the forearc sites are these:

1. Determining the temporal and compositional variation of arc volcanism as reflected in distal ash layers in the sediments.
2. Documenting the uplift and subsidence history of the forearc.
3. Identifying the age, composition, physical properties and fluid geochemistry of the outer forearc basement.
4. Conducting paleomagnetic studies of the forearc basement in an area away from thermal effects of later arc volcanism.

At the forearc sites we expect to drill volcaniclastic rocks, serpentinite, brecciated gabbro/diorite, and arc volcanic rocks.

*LG-3*

Site LG-3 is planned to penetrate the shallow platformal sequence of the Tonga Ridge to a depth of 800 mbsf. This will sample a regional seismic unconformity, referred to as the "A" horizon (Herzer and Exon, 1985; Austin et al., 1989). A large amount of multichannel (MCS) and single-channel seismic (SCS) data exists for the area around site LG-3. These are supplemented by GLORIA coverage, and a series of regional unpublished commercial and non-commercial seismic profiles (MCS and SCS). In the interests of safety at this site, possible structural closures observed in the shallow seismic stratigraphy on one of the profiles used to site LG-3 will be mapped in three dimensions aboard ship after 12-15 hours of seismic reflection profiling using *JOIDES Resolution's* seismic acquisition system. These data will be interpreted and FAXed back to ODP headquarters for review by PPSP before proceeding with drilling at this site.

*Site LG-6A*

This site lies at the trench-slope break where the distal forearc basin sediments thin significantly. Multichannel seismic data recorded in 1982 by the U.S. Geological Survey (L5-82-5P, line 12) and single-channel seismic reflection data from CD33 were used to site LG-6A. Despite extensive processing of line 12, resolution of reflectors at depth is poor. Some indications of a "basement" surface at varying depth (between 200 and 800 mbsf) have been noted on processed sections of line 12. The nature of the rock types that will be sampled and the depth of sampling of "basement" units are uncertain.

Alternate Sites

*LG-1 and LG-1A*

Contingency sites LG-1 and LG-1A lie on the western flank of the Central Lau Spreading Center (Fig. 1), which is the southerly propagating ridge that is advancing into the Lau Basin from the southeast end of the Peggy Ridge. The region of the proposed site was located using CD33 single-channel seismic reflection data. The precise site location will be determined using seismic data collected during the Leg 135 site approach.

*LG-9 and LG-9A*

Contingency sites LG-9 and LG-9A are located in the central Lau Basin on crust estimated to be less than 1 Ma. A sediment thickness of between 100 and 300 m overlies the basement. The region of the proposed site was located using CD33 single-channel seismic reflection data. The precise site location will be determined using seismic data collected during the Leg 135 site approach.

## DRILLING STRATEGY

Leg 135 will drill the proposed sites in the order shown on Table 2, departing Suva on 22 December 1990 and ending in Honolulu on 28 February 1991. The first three sites (LG-2, LG-7 and LG-10) will address backarc-basin targets before LG-3 and LG-6A, the arc-platform and forearc sites are occupied.

*LG-2*

The first hole at LG-2 will be cored using the advanced hydraulic piston corer (APC) and the extended core barrel (XCB), through the ~300-m sedimentary core sequence. Rotary (RCB) coring in a second hole will continue to shallow penetration of basement. Logging of the sedimentary section will then include standard Schlumberger runs, dual laterolog, magnetometer/susceptibility, and formation microscanner (FMS). The planned 200-m penetration of basement will require setting a reentry cone in a third hole and rotary coring to ~500 mbsf total depth (TD). A second logging run through the basement section will also include the borehole televiewer (BHTV).

*LG-7*

The drilling strategy for LG-7 will be to APC until refusal in the first hole through a thinner sedimentary section than exists at LG-2 (there may be as little as 100 m). The second hole will be rotary cored to bit destruction. Should the bit require change before achieving the proposed TD of 50 m into basement, we would drop a mini-cone to allow reentering the second hole. The second hole will be logged with the standard Schlumberger suite of logs, dual laterolog, magnetometer/susceptibility, FMS, and BHTV.

*LG-3 Survey*

Following drilling at LG-7, a seismic survey will be made in the vicinity of proposed site LG-3. This site is located within 100 km of known hydrocarbon occurrences (surface oil seeps) and a series of profiles will be acquired before drilling in order to ensure that no potential structural traps exist within the proposed sample section. The seismic data will be analyzed during drilling at the next site (LG-10) and the final site location will be confirmed after consultation with ODP headquarters and PPSP.

*LG-10*

The drilling strategy at LG-10 will be similar to that at LG-2, except that with the thinner sedimentary section (~100 M), only APC (without XCB) coring is likely in the first hole. Logging will take place in two stages as at LG-2, using the same suite of tools, but will be followed by a drill-string packer experiment in the interval made through the basement section in the second hole.

*LG-3*

Should LG-3 be confirmed as a suitable site after safety review on shore, drilling will involve APC coring to refusal (~150 mbsf) followed by XCB coring to ~400 mbsf in the first hole. A second hole will be RCB cored to ~800 mbsf TD, or the seismic horizon "A" objective (Austin et al., 1989), whichever is reached first. The second hole will be logged with the standard Schlumberger suite of logs, dual laterolog, magnetometer/susceptibility, FMS, and BHTV.

*LG-6A*

Two holes will be drilled at LG-6A. The first hole will be APC cored to refusal (~150 mbsf) followed by XCB coring to ~350 mbsf. A second hole will be RCB cored to a TD of 550 mbsf (50 m into basement). The uncertainty of the materials to be sampled negates accurate estimates of drilling life for RCB bits, and if necessary a mini-cone will be dropped to enable reentry to achieve the depth objective. The second hole will be logged with the standard Schlumberger suite of logs, dual laterolog, magnetometer/susceptibility, FMS, and BHTV.

## Drilling Alternatives

Depending on time availability, additional logging tools may be deployed. These could include the Uyeda thermistor probe, particularly at sites LG-2, LG-7, and LG-10.

Sites LG-2, LG-7, LG-10, LG-3, and LG-6A represent the optimum drilling program for Leg 135. An alternate site exists for LG-10 (LG-10A) and an additional backarc site LG-9 (with its alternate LG-9A) has also been approved. Should difficulties with any of the proposed primary sites allow time for an additional site, then LG-1 (or alternate LG-1A) has been approved within or adjacent to the propagating ridge axis of the Central Lau Spreading Center.

The drilling strategy at sites LG-9, LG-9A, LG-10A, LG-1, and LG-1A would be comparable to that described above for either LG-7 (shallow basement penetration) or LG-10 (deep basement penetration), depending on the drilling conditions and success with these primary holes.

## REFERENCES

Austin, J., Taylor, F. W., and Cagle, C. D., 1989. Seismic stratigraphy of the central Tonga Ridge. *Marine and Petroleum Geology,* 6:71-92.

Burns, R. E., Andrews, J. E., et al., 1973. *Init. Repts. DSDP,* 21. Washington (U.S. Govt. Printing Office).

Cole, J. W., Gill, J. B., and Woodhall, D., 1985. Petrologic history of the Lau Ridge, Fiji. *In* Scholl, D., and Vallier, T. J. (Eds.), *Geology and Offshore Resources of Pacific Island Arcs - Tonga Region.* Circum-Pacific Council for Energy and Mineral Resources, Earth Sciences Series, 2:379-414.

Cole, W. S., 1970. Larger foraminifera of late Eocene age from 'Eua, Tongan Islands. *U.S. Geol. Surv. Prof. Pap.* 640-B:1-15.

Cunningham, J. K. and Anscome, K., 1985. Geology of 'Eua and other islands, Kingdom of Tonga. *In* Scholl, D., and Vallier, T. L. (Eds.), *Geology and Offshore Resources of Pacific Island Arcs - Tonga Region.* Circum-Pacific Council for Energy and Mineral Resources, Earth Sciences Series, 2:221-258.

Dewey, J., and Bird, J., 1971. Origin and emplacement of the ophiolite suite: Appalachian ophiolites in Newfoundland. *J. Geophys. Res.,* 76:3179-3206.

Duncan, R., Vallier, T. L., and Falvey, D., 1985. Volcanic episodes at 'Eua, Tonga Islands. *In* Scholl, D., and Vallier, T. L. (Eds.), *Geology and Offshore Resources of Pacific Island Arcs - Tonga Region.* Circum-Pacific Council for Energy and Mineral Resources, Earth Sciences Series, 2:281-290.

Ewart, A., and Bryan, W. B., 1972. The petrology and geochemistry of the igneous rocks from 'Eua, Tonga. *Geol. Soc. Am. Bull.,* 83:3281-3298.

Ewart, A., Bryan, W. B., and Gill, J. 1973. Mineralogy and geochemistry of the younger volcanic islands of Tonga, southwest Pacific. *Jour. Petrol.,* 14:429-465.

Hawkins, J. W., 1974. Geology of the Lau Basin, a marginal sea behind the Tonga Arc. *In* Burk, C., and Drake, C. (Eds.), *Geology of Continental Margins.* New York (Springer-Verlag), 505-520.

Hawkins, J. W., 1976. Petrology and geochemistry of basaltic rocks of the Lau Basin. *Earth Planet. Sci. Lett.,* 28:283-298.

Hawkins, J. W., Bloomer, S. H., Evans, C. A., and Melchior, J. T., 1984. Evolution of intra-oceanic arc-trench systems. *Tectonophysics,* 102:174-205.

Hawkins, J., and Falvey, D., 1985. Petrology and andesitic dikes and flows from 'Eua, Tonga. *In* Scholl, D., and Vallier, T. L. (Eds.), *Geology and Offshore Resources of Pacific Island Arcs - Tonga Region.* Circum-Pacific Council for Energy and Mineral Resources, Earth Sciences Series, 2:269-280.

Hawkins, J. W., and Melchior, J. T., 1985. Petrology of Mariana Trough and Lau Basin basalts. *Jour. Geophys. Res.* 90:11431-11468.

Herzer, R. H., and Exon, N. F., 1985. Structure and basin analysis of the southern Tonga Forearc. *In* Scholl, D., and Vallier, T. L. (Eds.), *Geology and Offshore Resources of Pacific Island Arcs - Tonga Region.* Circum-Pacific Council for Energy and Mineral Resources. Earth Sciences Series, 2:55-74.

JOI, 1981. Conference on scientific ocean drilling. Washington, DC (JOI, Inc.).

JOI-ESF, 1987. Report of the second conference on scientific ocean drilling. Washington, DC (JOI, Inc.).

Karig, D. E., 1970. Ridges and basins of the Tonga-Kermadec island arc system. *Jour. Geophys. Res.,* 75:239-254.

Lawver, L., Hawkins, J., Sclater, J., 1976. Magnetic anomalies and crustal dilation in the Lau Basin. *Earth Planet. Sci. Lett.,* 3:27-35.

Malahoff, A., Feden, R. H., and Fleming, B., 1982. Magnetic anomalies and tectonic fabric of marginal basins north of New Zealand. *Jour. Geophys. Res.,* 87:4109-4125.

Nautilau, 1990. Hydrothermal activity in the Lau Basin. *EOS, Trans. Am. Geophys. Union,* 71:678-679.

Parson, L., Pearce, J., Murton, B., Hodkinson, R., et al., 1990. The role of ridge jumps and ridge propagation in the tectonic evolution of the Lau backarc basin, SW Pacific. *Geology,* 18:470-473.

Poreda, R., 1985. $^3$He and deuterium in back-arc basalts: Lau Basin and the Mariana Trough. *Earth Planet. Sci. Lett.*, 73:244-254.

Sinton, J. M., Price, R. C., and Johnson, K. T., 1985. Petrology and geochemistry of submarine lavas of the Lau and North Fiji Basins. *In* Kroenke, L., and Eade, J. V. (Eds.), *Basin Formation, Ridge Crest Processes and Metallogenesis in the North Fiji Basin*. Circum-Pacific Council for Energy and Mineral Resources, Earth Science Series.

Stearns, H. T., 1971. Geologic setting of an Eocene fossil deposit on 'Eua, Tonga. *Geol. Soc. Am. Bull.*, 82:2541-2552.

Vallier, T., Jenner, G., Frey, F., Gill, J., Hawkins, J., Morris, J., et al., in press. Subalkaline andesite from Valu Fa Ridge, a back-arc spreading center in the Lau Basin: Chemical constraints on magma genesis. *Geol. Soc. Am. Bull.*

Volpe, A., Macdougall, J. D., and Hawkins, J. W., 1988. Lau Basin basalts: trace element and Sr-Nd isotopic evidence for heterogeneity in backarc basin mantle. *Earth Planet. Sci. Lett.*, 90:174-186.

von Stackelberg, U., Morton, J. L., et al., 1985. *Hydrothermal Sulfide Deposits in Back-arc Spreading Centers in the Southwest Pacific*. B.G.R. Circular 2, 14, Hannover, Germany.

Woodhall, D., 1985. Geology of the Lau Ridge. *In* Scholl, D., and Vallier, T. L. (Eds.), *Geology and Offshore Resources of Pacific Island Arcs - Tonga Region*. Circum-Pacific Council for Energy and Mineral Resources, Earth Sciences Series, 2:351-378.

## TABLE CAPTIONS

Table 1. Proposed drill sites, Leg 135.

Table 2. Tentative drilling schedule, Leg 135.

## FIGURE CAPTIONS

Figure 1. Generalized map of the Lau Basin showing the major petrologic, tectonic, and morphologic features, and the sites planned as primary (priority 1) or alternate (priority 2) drilling targets. The location of DSDP Site 203 (Burns, Andrews, et al., 1973) is also shown.

Figure 2. Schematic representation of the two possible models for evolution of the Lau Basin discussed in the text. Figure 2A represents the pre-Lau Basin volcanic arc. Figure 2B represents the model considering the Tofua Arc to be a continuation of the earlier Lau Ridge arc. Figure 2C shows the newer model of Hawkins and Melchior (1985) proposing that Lau Basin spreading and Tofua Arc volcanism have occurred in the forearc region of the earlier Lau Ridge arc. The proposed schematic locations of ODP Leg 135 drill sites and the DSDP Leg 21 sites in the Lau Basin are also shown.

Table 1. Proposed Drill Sites, Leg 135.

| Site | Latitude | Longitude | Water Depth(m) | Proposed Penetration(m) |
|---|---|---|---|---|
| LG-1 | 19°03.0'S | 176°36.0'W | 2475 | 175[1] |
| LG-1A | 19°14.8'S | 176°31.9'W | 2405 | 175[1] |
| LG-2 | 18°34.4'S | 177°51.0'W | 2704 | 500 |
| LG-3 | 22°13.0'S | 175°40.5'W | 675 | 800[2] |
| LG-6A | 23°20.0'S | 175°10.0'W | 5665 | 550 |
| LG-7 | 18°29.9'S | 177°17.0'W | 2913 | 150[3] |
| LG-9 | 20°07.6'S | 176°42.8'W | 2576 | 350 |
| LG-9A | 20°50.0'S | 176°51.5'W | 2285 | 350 |
| LG-10 | 20°05.1'S | 176°34.3'W | 1910 | 300 |
| LG-10A | 20°48.7'S | 176°38.0'W | 2385 | 300[4] |

---

[1]Sites LG-1 and LG-1A approved by PPSP for penetration to 200 mbsf.

[2]PPSP has approved penetration to 800 mbsf pending their inspection of crosslines collected aboard *JOIDES Resolution* prior to drilling this site.

[3]Site LG-7 approved by PPSP for penetration to 300 mbsf.

[4]Site LG-10A approved by PPSP for penetration to 350 mbsf.

Table 2: Tentative drilling schedule, Leg 135.

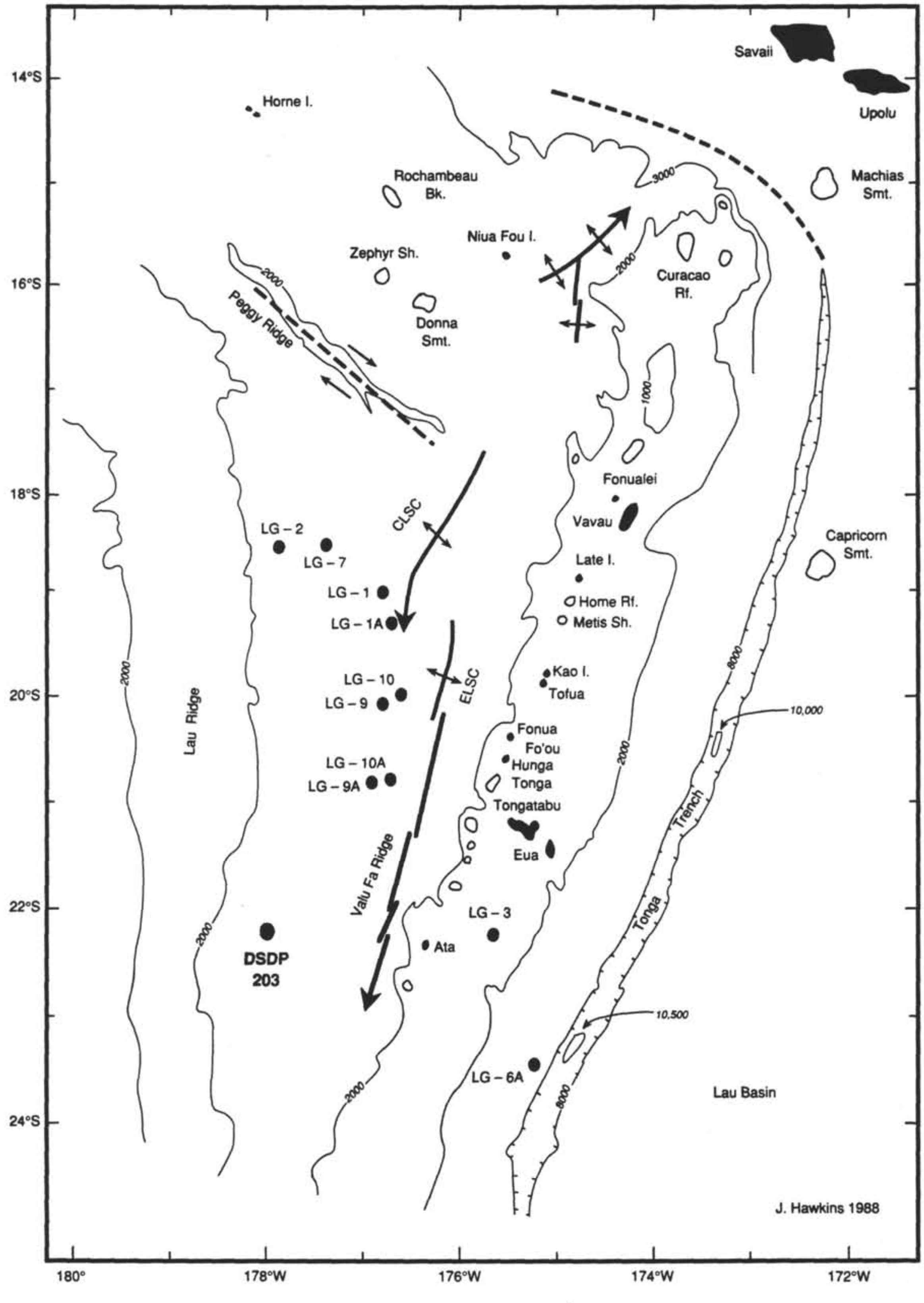
Leg 135 departs Suva, Fiji, at 1200 hr on 22 December 1990.

| | Date | Time on Site (days) | Transit Time (days) |
|---|---|---|---|
| Transit Suva to LG-2 | | | 1 |
| Arr LG-2 | 23 Dec 90 | 15.8 | |
| Lv LG-2 | 8 Jan 91 | | |
| Transit LG-2 to LG-7 | | | 0.1 |
| Arr LG-7 | 8 Jan | 4.2 | |
| Lv LG-7 | 13 Jan | | |
| Transit LG-7 to LG-3 | | | 0.7 |
| Arr LG-3 (SURVEY) | 13 Jan | 0.6 | |
| Lv LG-3 | 13 Jan | | |
| Transit LG-3 to LG-10 | | | 0.6 |
| Arr LG-10 | 14 Jan | 13.5 | |
| Lv LG-10 | 27 Jan | | |
| Transit LG-10 to LG-3 | | | 0.6 |
| Arr LG-3 (DRILL) | 27 Jan | 6.7 | |
| Lv LG-3 | 3 Feb | | |
| Transit LG-3 to LG-6A | | | 0.4 |
| Arr LG-6A | 3 Feb | 12.3 | |
| Lv LG-6A | 15 Feb | | |
| Transit LG-6A to Honolulu | | | 11.5 |

Leg 135 ends in Honolulu on 28 February 1991.

Total = 68 days

Note: All transit times estimated at 10 kt.



14°S
16°S
18°S
20°S
22°S
24°S
180°
178°W
176°W
174°W
172°W
Savaii
Upolu
Horne I.
Rochambeau
Bk.
Machias
Smt.
Niua Fou I.
Zephyr Sh.
Curacao
Rf.
Donna
Smt.
Peggy Ridge
2000
3000
1000
Fonualei
Vavau
CLSC
LG – 2
LG – 7
Capricorn
Smt.
Late I.
LG – 1
Home Rf.
LG – 1A
Metis Sh.
LG – 10
Kao I.
LG – 9
Tofua
ELSC
8000
10,000
Lau Ridge
Fonua
Fo'ou
LG – 10A
Hunga
LG – 9A
Tonga
Tongatabu
Eua
Valu Fa Ridge
Trench
Tonga
LG – 3
DSDP
203
Ata
10,500
LG – 6A
Lau Basin
J. Hawkins 1988


Figure 1.

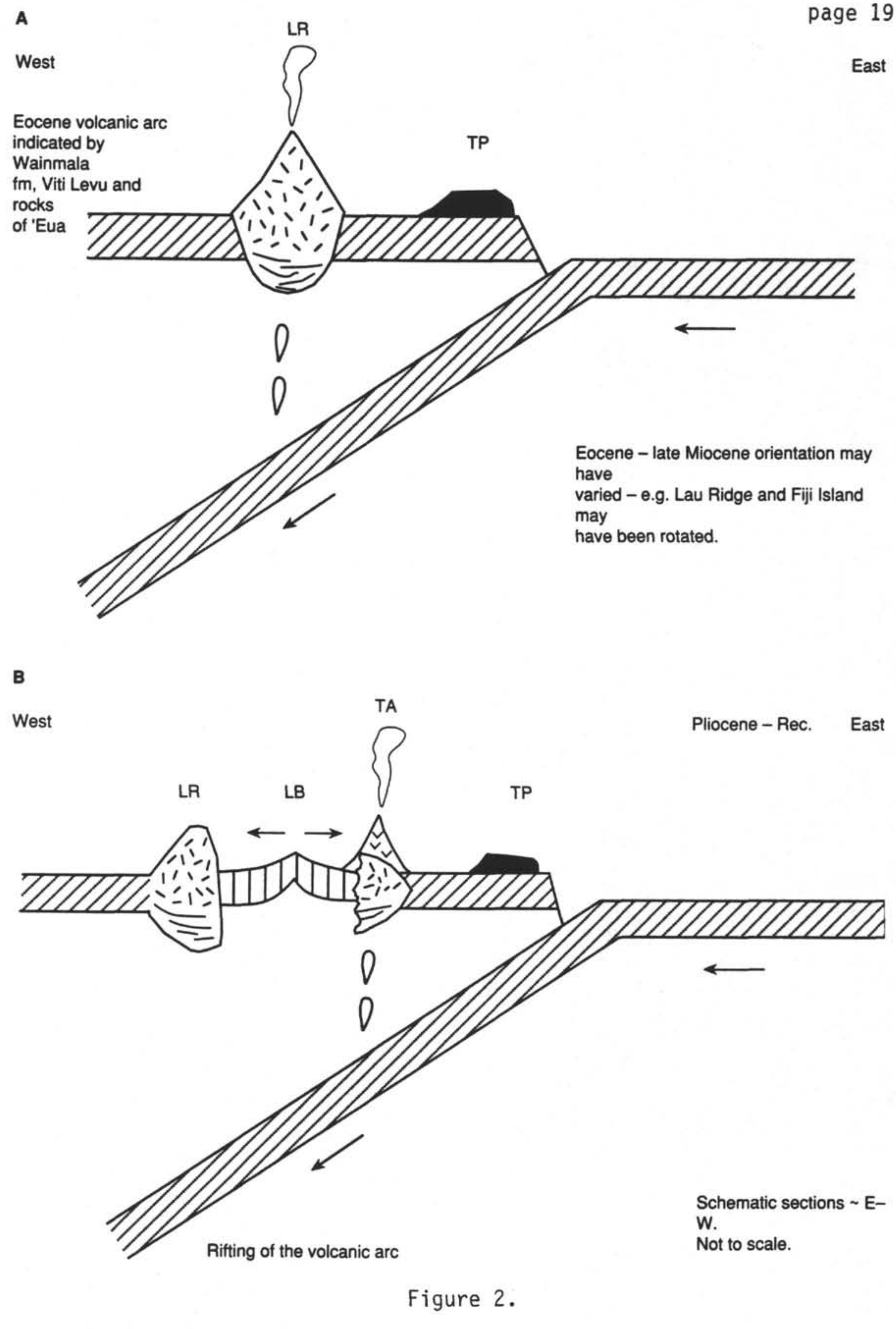

A
LR
West
East
Eocene volcanic arc
indicated by
Wainmala
fm, Viti Levu and
rocks
of 'Eua
TP
Eocene – late Miocene orientation may
have
varied – e.g. Lau Ridge and Fiji Island
may
have been rotated.
B
TA
West
Pliocene – Rec.
East
LR
LB
TP
Schematic sections ~ E–
W.
Not to scale.
Rifting of the volcanic arc

Figure 2.

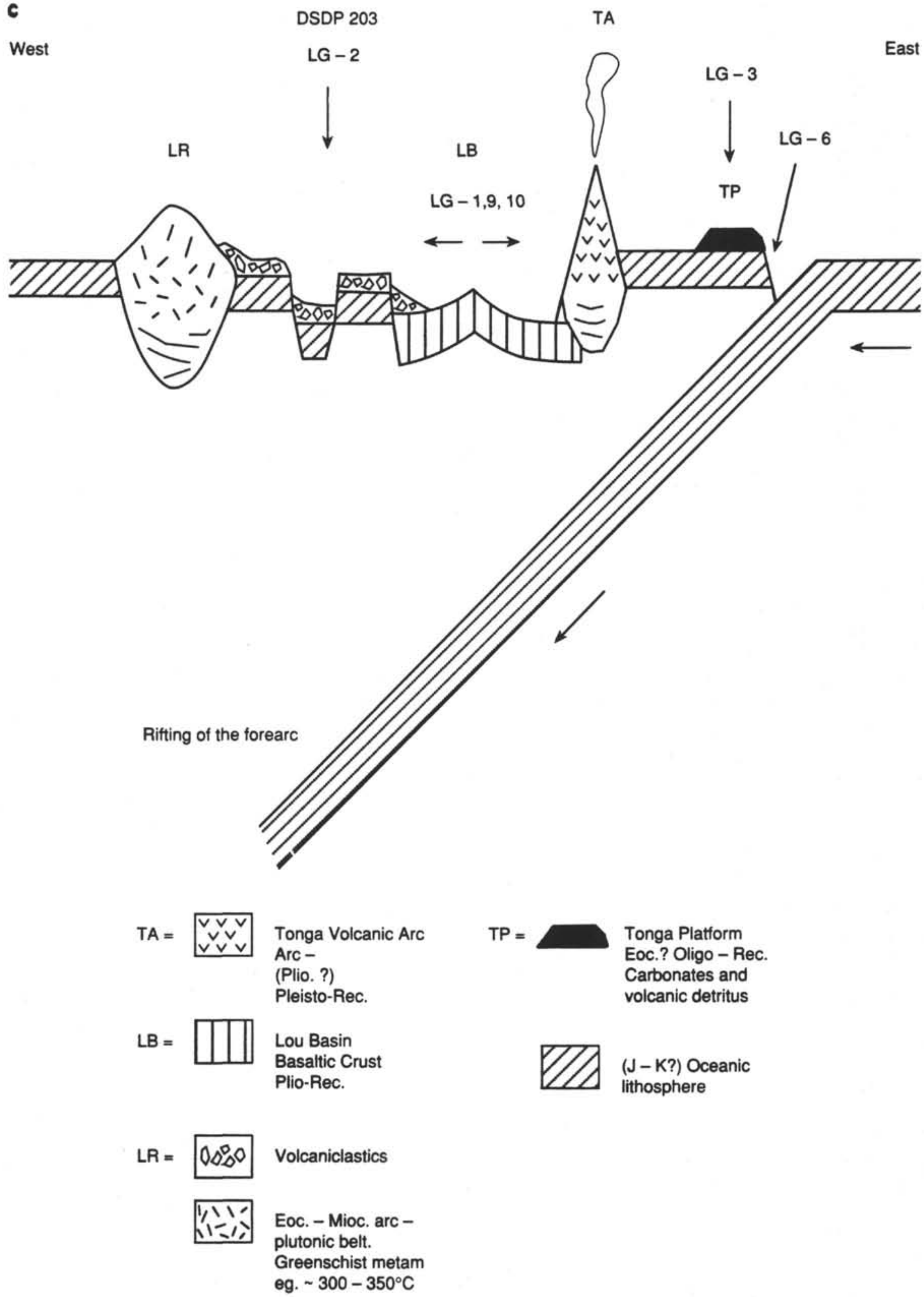



Figure 2 continued.

SITE: LG-1 PRIORITY: 2

POSITION: 19°03.0'S
176°36.0'W

WATER DEPTH: 2475 m SEDIMENT THICKNESS: 0-100 m

PROPOSED DRILLING PROGRAM: Hole A: APC to 50 mbsf. Hole B: RCB to bit destruction (~175 mbsf), log hole.

SEISMIC RECORD: *Charles Darwin* cruise CD33, 1015Z/133. Precise site to be located within 5-km radius of target site using seismic data collected during Leg 135 site approach.

LOGGING: Standard Schlumberger logging, dual laterolog, magnetometer/susceptibility, formation microscanner, borehole televiewer.

OBJECTIVES: LG-1 or alternate site LG-1A are intended to penetrate the feather edge of young (<0.5 Ma) oceanic crust generated at the propagator. This crust is speculated to overlie the rifted, dike-injected, older backarc crust (e.g., 1.5-2 Ma). The objectives of drilling either LG-1 or LG-1A would be to combine an understanding of the early petrologic character of the propagator with a precise assessment of the time hiatus between it and pre-existing backarc crust. LG-1, lying some 40 km behind the propagating tip, would give us a maximum range in the compositional variability of magmas (i.e., extent of differentiation) developed as the spreading ridge magma system evolves and matures. These data would be compared to fresh samples already dredged from the rift tip.

NATURE OF SEDIMENT/ROCKS ANTICIPATED: Calcareous oozes with minor pumice overlying basalt.

SITE: LG-1A PRIORITY: 2

POSITION: 19°14.8'S
176°31.9'W

WATER DEPTH: 2405 m SEDIMENT THICKNESS: 0-100 m

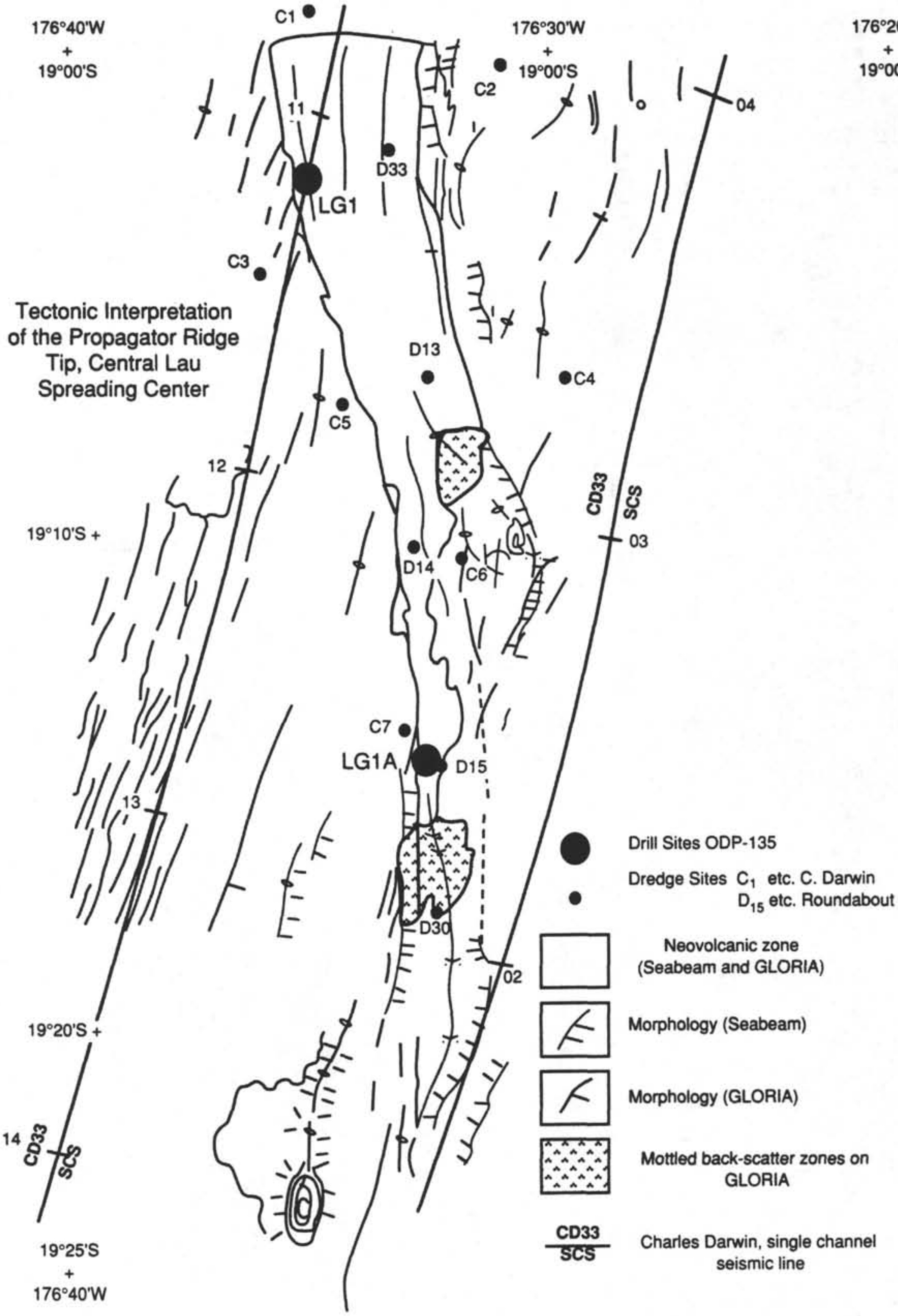
PROPOSED DRILLING PROGRAM: Hole A: APC to 50 mbsf. Hole B: RCB to bit destruction (~175 mbsf), log hole.

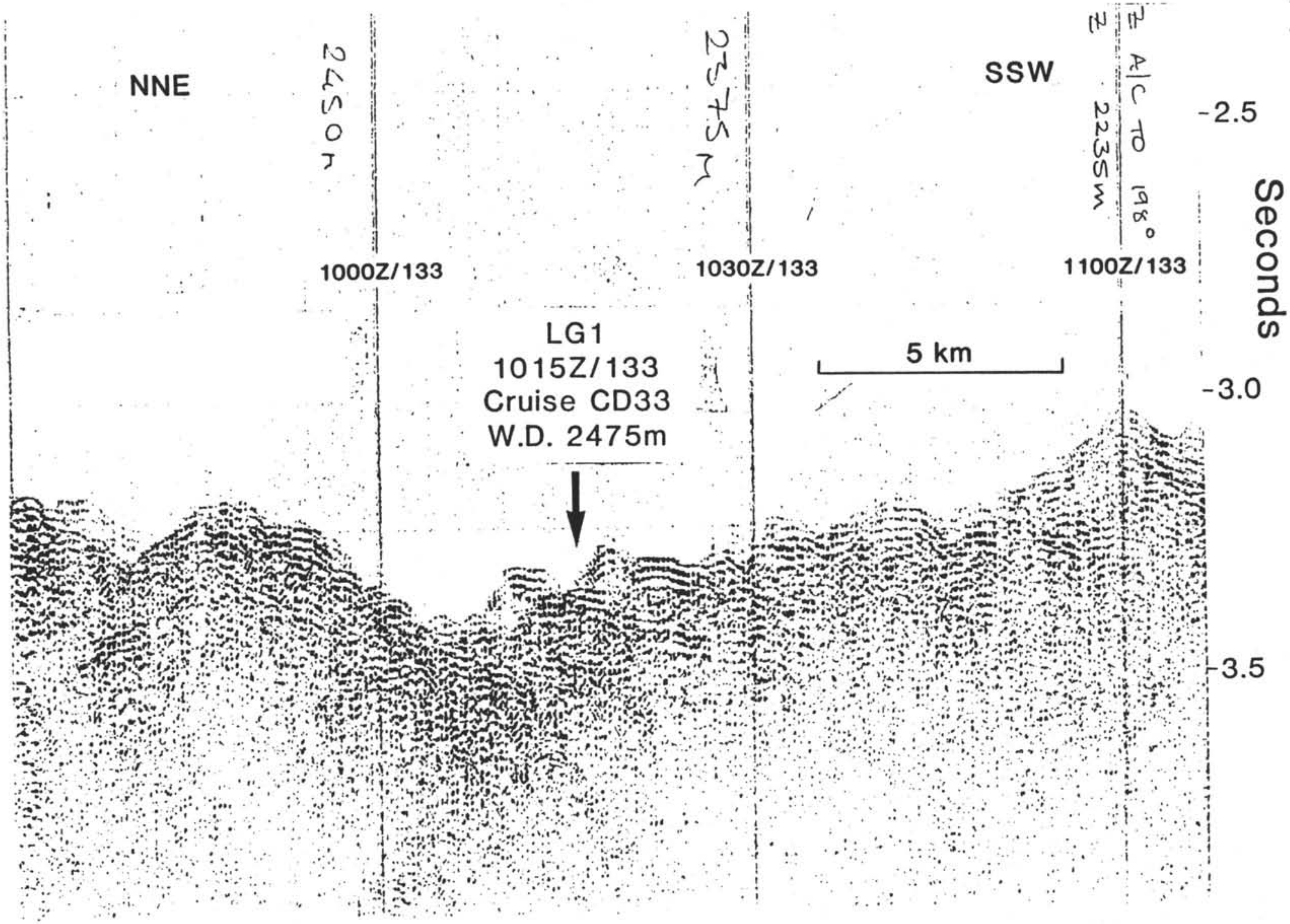
SEISMIC RECORD: *Charles Darwin* cruise CD33, 0230Z/131. Precise site to be located within 5-km radius of target site using seismic data collected during site approach.

LOGGING: Standard Schlumberger logging, dual laterolog, magnetometer/susceptibility, formation microscanner, borehole televiewer.

OBJECTIVES: LG-1 or alternate site LG-1A is intended to penetrate the feather edge of young (<0.5 Ma) oceanic crust generated at the propagator. This crust is speculated to overlie the rifted, dike-injected, older backarc crust (e.g., 1.5-2 Ma). The objectives of drilling either LG-1 or LG-1A would be to combine an understanding of the early petrologic character of the propagator with a precise assessment of the time hiatus between it and pre-existing backarc crust. LG-1, lying some 40 km behind the propagating tip, would give us a maximum range in the compositional variability of magmas (i.e., extent of differentiation) developed as the spreading ridge magma system evolves and matures. These data would be compared to fresh samples already dredged from the rift tip.

NATURE OF SEDIMENT/ROCKS ANTICIPATED: Calcareous oozes with minor pumice overlying basalt.


176°40'W + 19°00'S
176°30'W + 19°00'S
176°20'W + 19°00'S
Tectonic Interpretation of the Propagator Ridge Tip, Central Lau Spreading Center
C1
C2
C3
C4
C5
C6
C7
D13
D14
D15
D30
D33
LG1
LG1A
11
12
13
14
04
03
02
CD33 SCS
19°10'S +
19°20'S +
19°25'S + 176°40'W
Drill Sites ODP-135
Dredge Sites C1 etc. C. Darwin
D15 etc. Roundabout
Neovolcanic zone (Seabeam and GLORIA)
Morphology (Seabeam)
Morphology (GLORIA)
Mottled back-scatter zones on GLORIA
CD33 / SCS Charles Darwin, single channel seismic line


NNE
SSW
2450m
2375m
A/C TO 198°
2235m
1000Z/133
1030Z/133
1100Z/133
LG1
1015Z/133
Cruise CD33
W.D. 2475m
5 km
-2.5
-3.0
-3.5
Seconds

SITE: LG-2 PRIORITY: 1

POSITION: 18°34.4'S
177°51.0'W

WATER DEPTH: 2704 m SEDIMENT THICKNESS: 300 m

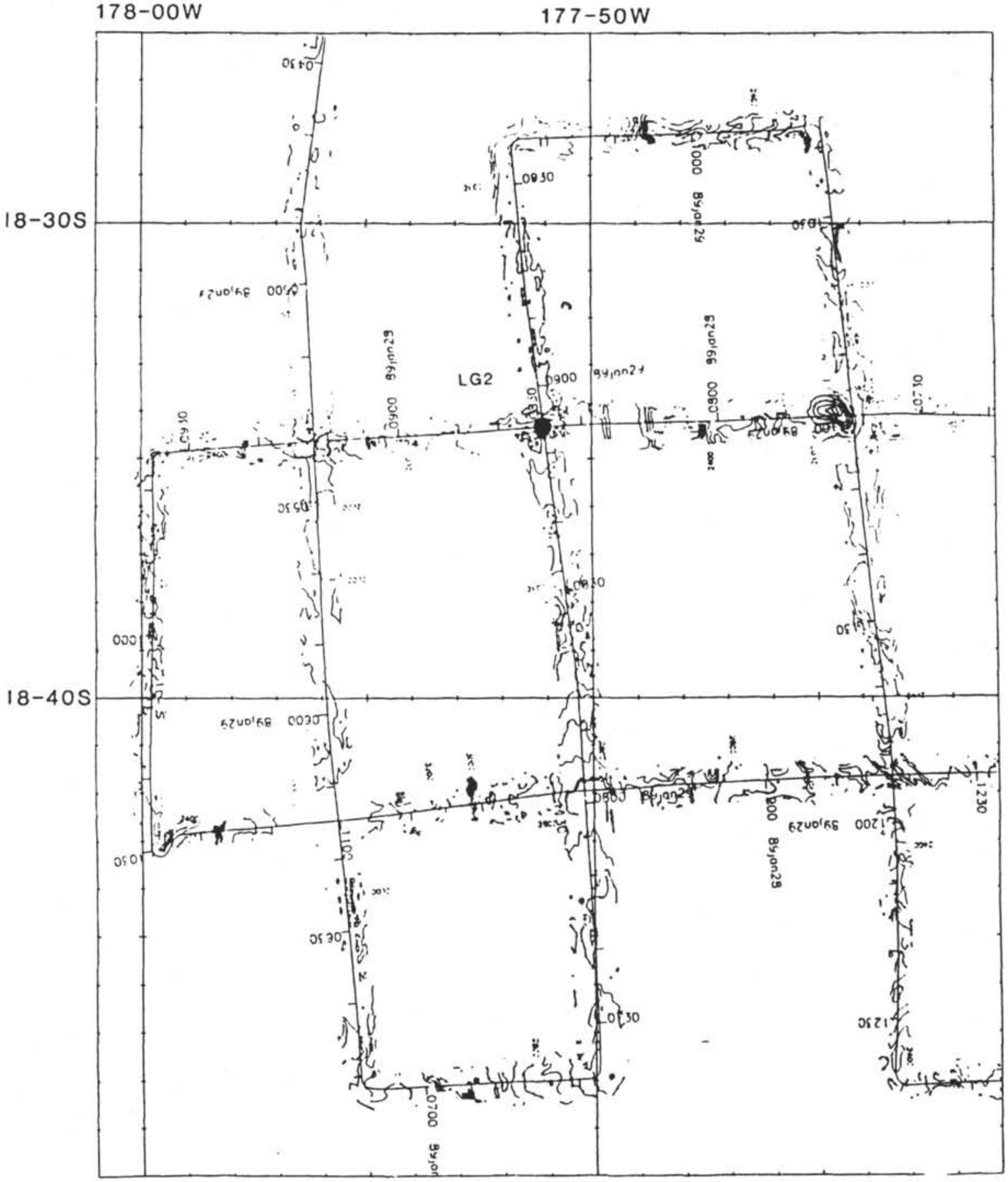
PROPOSED DRILLING PROGRAM: Hole A: APC/XCB to 150 mbsf, XCB to basement (300 mbsf). Hole B: RCB to 350 mbsf, log hole. Hole C: set reentry cone, RCB to 500 mbsf, log hole.

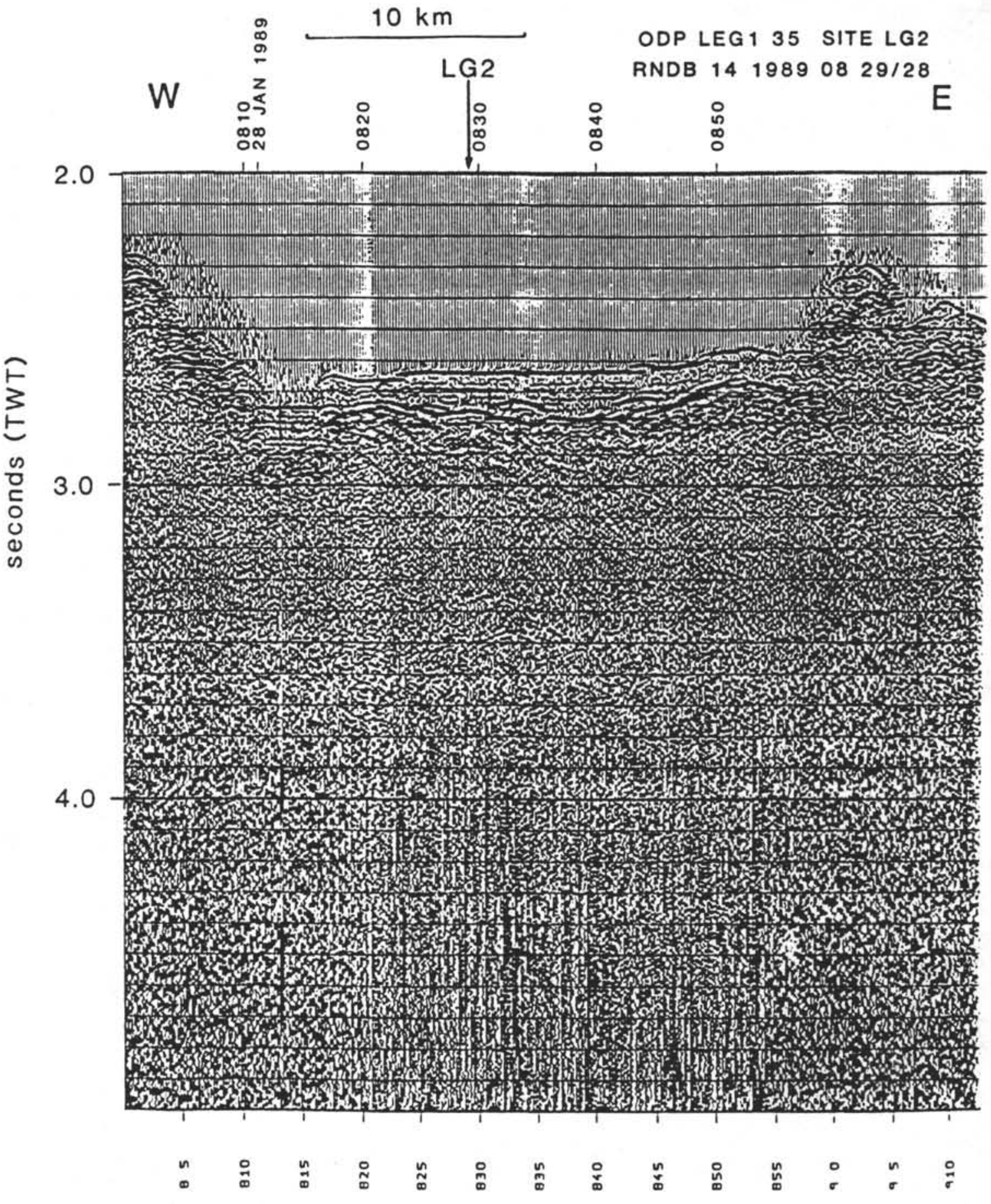
SEISMIC RECORD: *Charles Darwin* cruise 33, 1310Z/143 and *T. Washington* cruise ROUNDABOUT 14, 1989, 0829Z/28 Jan 89.

LOGGING: Standard Schlumberger logging, dual laterolog, magnetometer/susceptibility, formation microscanner, borehole televiewer (basement only).

OBJECTIVES: The location of the site was selected in order to sample crust formed in the first 0.5 m.y. of crustal dilation. Interpretation of magnetic anomaly data, gravity data, and geologic data from dredged samples suggests that the crust at site LG-2 is the oldest backarc basin crust. The age of the basal sediment will be critical for determining this and for identifying the prominent magnetic anomaly that marks the west side of the Lau Basin. The stratigraphy and petrology of the sediments will give a record of the subsidence history of the Lau Basin and the concurrent uplift and erosion history of the Lau Ridge. Changes in Lau Ridge arc volcanic activity and magma composition will also be preserved in the sedimentary record. Knowledge of basement rock chemistry will be important for understanding the extent of compositional changes as the volcanic products of the backarc spreading centers evolved to their present MORB-like chemistry. Additional drilling objectives at site LG-2 include documenting the physical and chemical properties of the initial backarc basin crust, hydrothermal activity, metalliferous deposits, and the diagenetic history of the sediments. The setting of this site is comparable to the setting for DSDP Site 203, which did not reach basement and recovered samples only by spot coring. We expect to recover similar sediments, namely calcareous oozes interbedded with volcanic ash and clastic volcanic material.

NATURE OF SEDIMENT/ROCKS ANTICIPATED: Calcareous oozes interbedded with volcanic ash and clastic volcanic material overlying basalt.


178-00W
177-50W
18-30S
18-40S
LG2


10 km
ODP LEG1 35 SITE LG2
RNDB 14 1989 08 29/28
LG2
W
E
0810
28 JAN 1989
0820
0830
0840
0850
2.0
3.0
4.0
seconds (TWT)
8 5
810
815
820
825
830
835
840
845
850
855
9 0
9 5
910

SITE: LG-3 PRIORITY: 1

POSITION: 22°13.0'S
175°40.5'W

WATER DEPTH: 675m SEDIMENT THICKNESS: >2000 m?

PROPOSED DRILLING PROGRAM: Hole A: APC to ~150 mbsf, XCB to 400 mbsf. Hole B: RCB to total depth (800 mbsf), log hole.

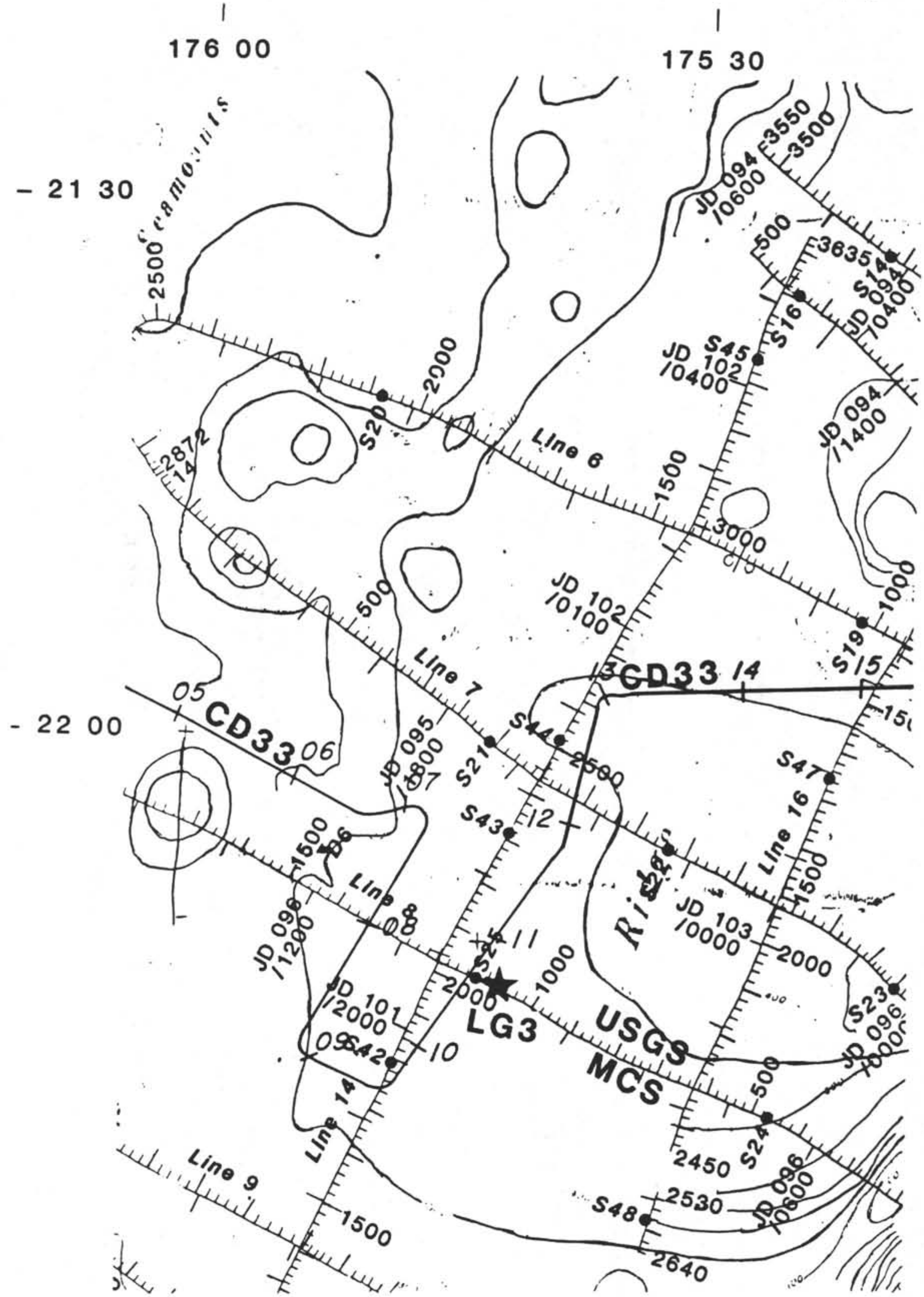
SEISMIC RECORD: USGS L5-82, MCS line 8, SP1050, tie with *Charles Darwin* cruise CD33, 1048Z/147, 26 May 1988. Additional single-channel seismic data will be collected during Leg 135 to support siting of LG-3.

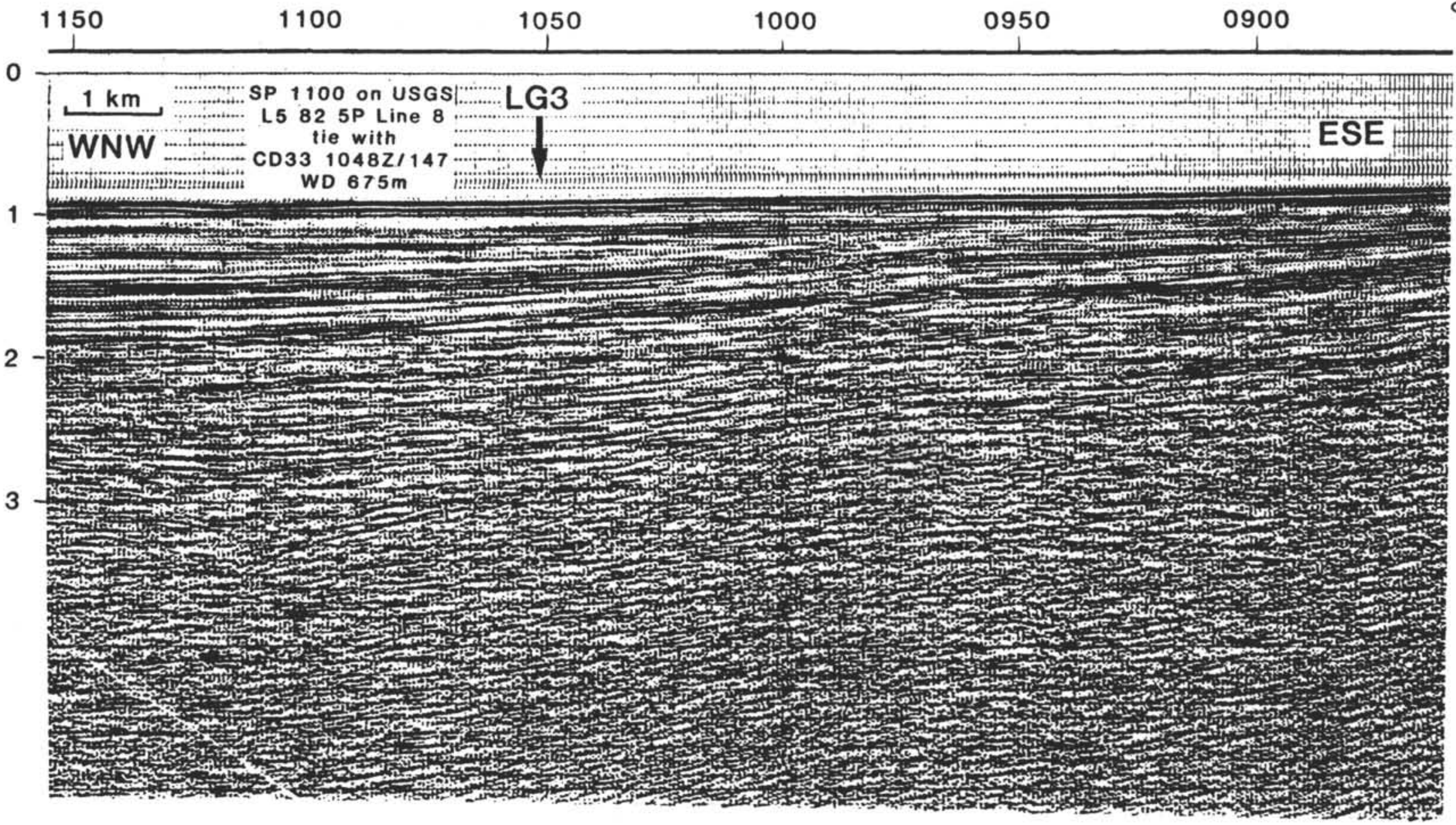
LOGGING: Standard Schlumberger logging, dual laterolog, magnetometer/susceptibility, formation microscanner, borehole televiewer.

OBJECTIVES: Penetrating the shallow platformal sequence of the Tonga Ridge to a depth of 900 m will permit sampling a regional seismic unconformity, referred to as the "A" horizon (Herzer and Exon, 1985; Austin et al., 1989), which is thought to be late Miocene to Pliocene in age, corresponding to the initiation and earliest history of formation of the Lau Basin. Accurate dating of this horizon, and of smaller scale younger stratigraphic/angular unconformities, will enable an accurate assessment of uplift and subsidence history, and a correlation of basin and regional tectonics. The effects of any ridge jumps, ridge propagation, and progressive forearc disruption by collision with the Louisville Seamount Chain should also be discernible. Neotectonics of the platform will be assessed using strain-regime analysis during logging. Sediments expected are volcaniclastic rocks interbedded with limestone.

Specific objectives for this site are to determine (1) the age of horizon "A" (interpreted as dating the time of initial opening of the Lau Basin), (2) the age of the beginning of renewed volcanism on the Tofua Arc (or evidence for continued volcanism), and (3) the geochemical character, and evidence for evolution, of arc volcanism above horizon "A."

NATURE OF SEDIMENT/ROCKS ANTICIPATED: Volcaniclastic rocks interbedded with limestone.


176 00
175 30
- 21 30
- 22 00
Line 6
Line 7
Line 8
Line 9
Line 14
Line 16
CD33
LG3
USGS
MCS
S20
S21
S42
S43
S44
S45
S47
S48
S16
S19
S23
S24
JD 094 /0600
JD 094 /0400
JD 094 /1400
JD 102 /0400
JD 102 /0100
JD 095 /1800
JD 096 /1200
JD 101 /2000
JD 103 /0000
JD 096 /0600
2500
2000
1500
1000
500
3000
3550
3500
3635
2450
2530
2640


1150
1100
1050
1000
0950
0900
0
1
2
3
1 km
WNW
SP 1100 on USGS
L5 82 5P Line 8
tie with
CD33 1048Z/147
WD 675m
LG3
ESE

SITE: LG-6A PRIORITY: 1

POSITION: 23°20.0'S
175°10.0'W

WATER DEPTH: 5665 m SEDIMENT THICKNESS: ~500 m

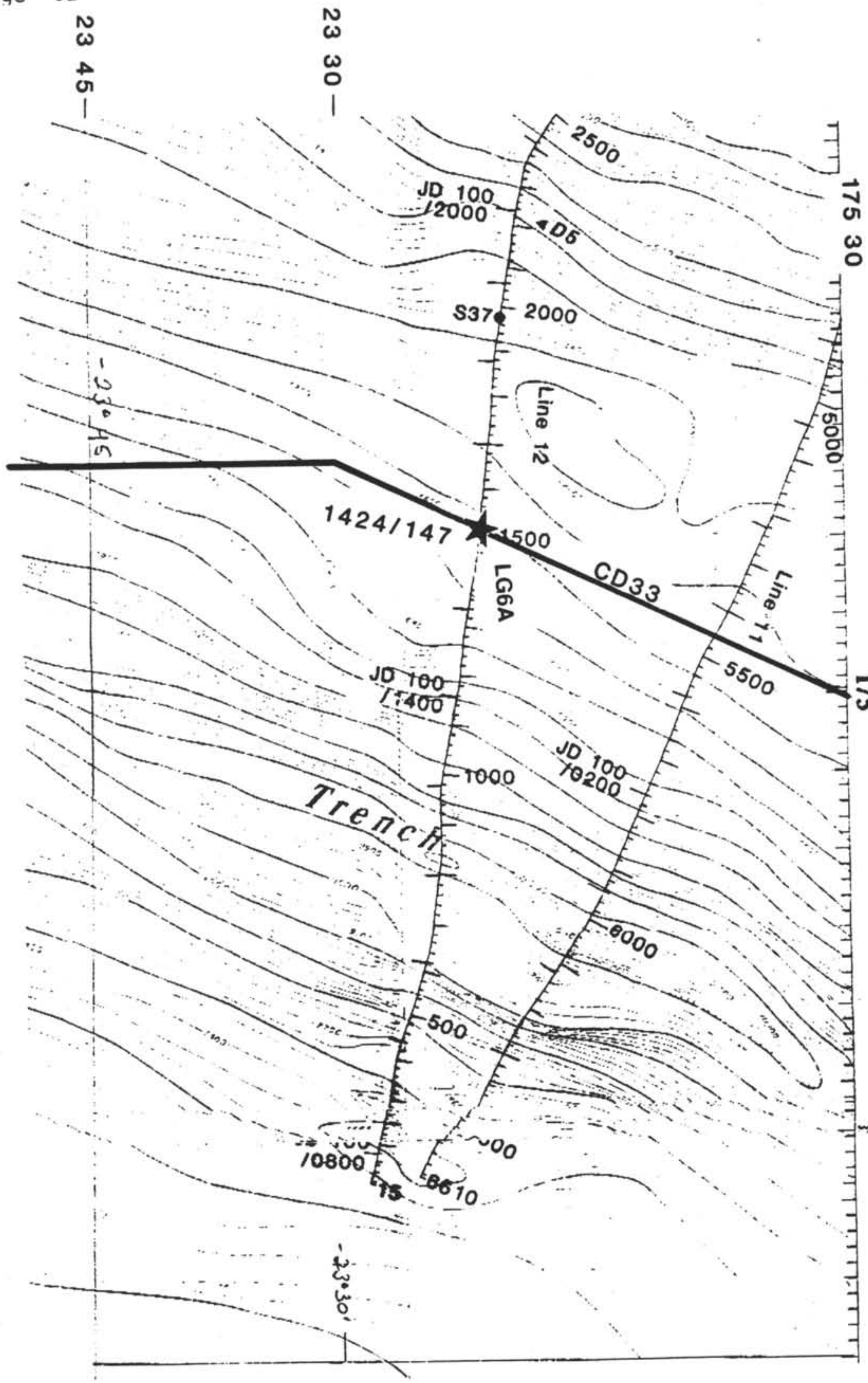
PROPOSED DRILLING PROGRAM: Hole A: APC to ~150 mbsf, XCB to 350 mbsf. Hole B: RCB to 550 mbsf (50 m into basement), log hole.

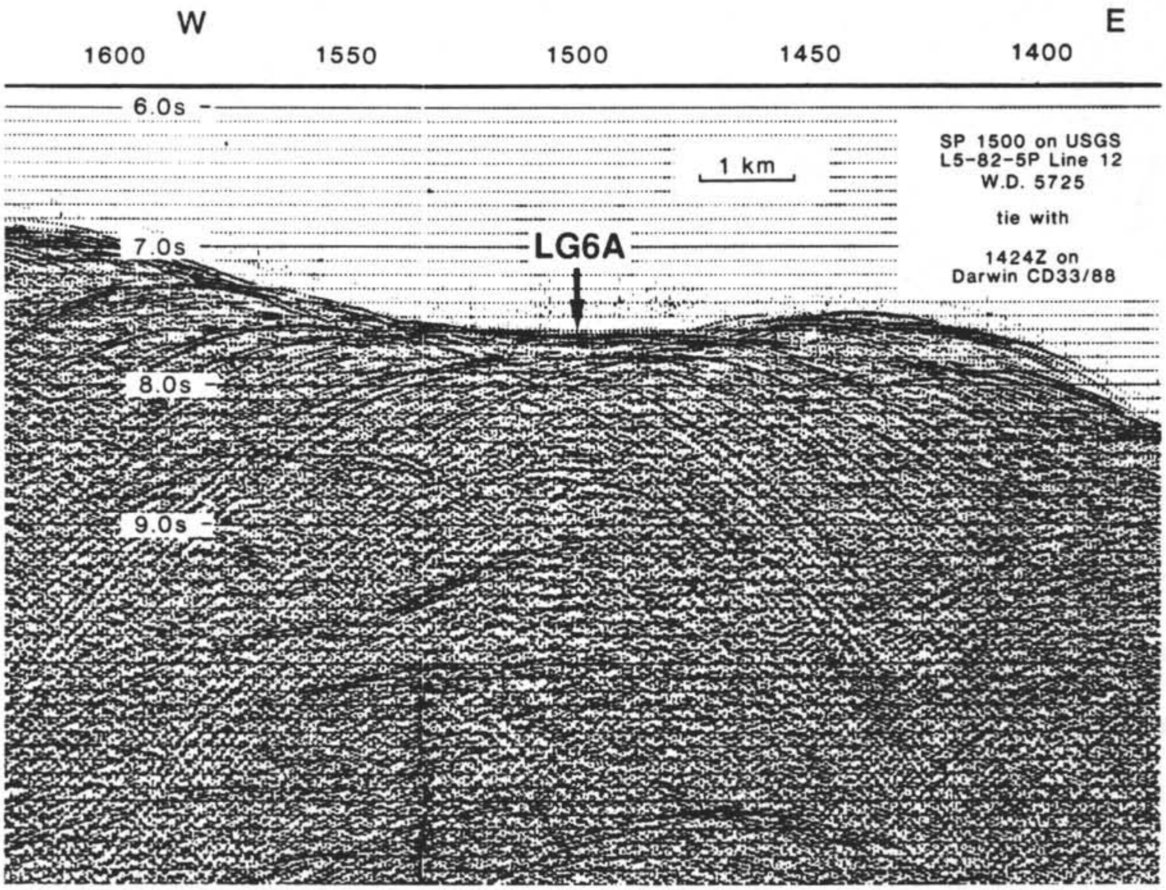
SEISMIC RECORD: USGS L5-82-5P, line 12, SP1500, tie with *Charles Darwin* cruise CD33, 1424Z/147.

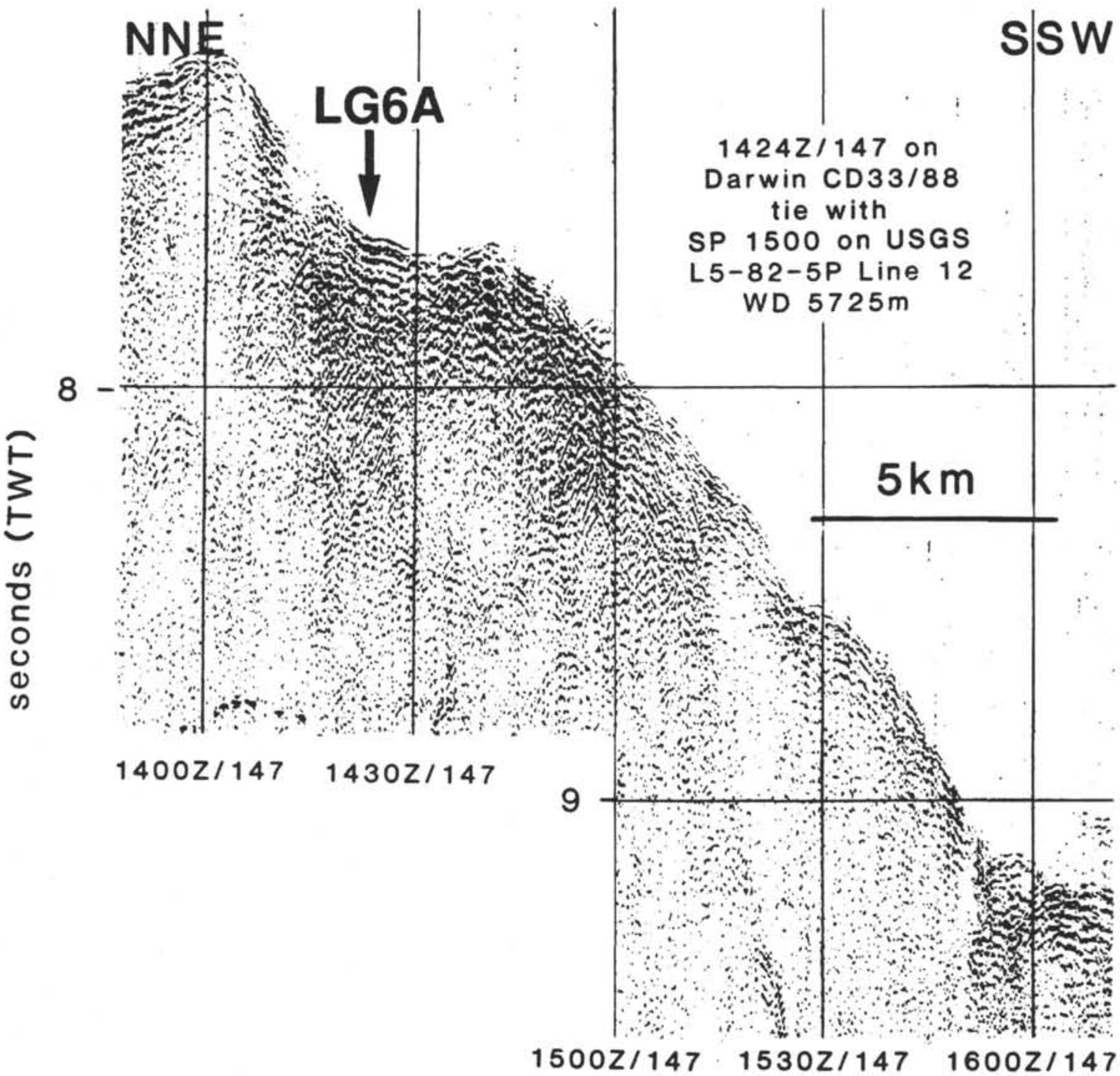
LOGGING: Standard Schlumberger logging, dual laterolog, magnetometer/susceptibility, formation microscanner, borehole televiewer.

OBJECTIVES: The principal objective for forearc site LG-6A is to recover ~500 m of sediment overlying *in-situ* forearc basement and to core 50 m of that basement. This will provide an adequate section to characterize the basement, to assign it a minimum age, to make an estimate of the uplift/subsidence history of the forearc and to establish a tephrochronology for arc volcanism in the Tofua Arc. Specific objectives for this site are to (1) determine the petrology of the igneous/metamorphic basement and compare it with the Mariana and Bonin forearcs, (2) conduct paleomagnetic studies of the forearc basement in an area away from thermal effects of later arc volcanism, (3) ascertain the physical properties and fluid geochemistry of forearc basement, and (4) understand the volcanic history of the Tofua Arc and the uplift/subsidence history of the forearc.

NATURE OF SEDIMENT/ROCKS ANTICIPATED: Volcaniclastic rocks, serpentinite, brecciated gabbro/diorite, and arc volcanic rocks.


23 45
23 30
175 30
175°
2500
JD 100 /2000
D5
S37
2000
Line 12
5000
1424/147
1500
LG6A
CD33
Line 11
5500
JD 100 /1400
1000
JD 100 /0200
Trench
6000
500
/0800
15
8610
-23°30'


W
E
1600
1550
1500
1450
1400
6.0s
1 km
SP 1500 on USGS
L5-82-5P Line 12
W.D. 5725
tie with
1424Z on
Darwin CD33/88
7.0s
LG6A
8.0s
9.0s


NNE
SSW
LG6A
1424Z/147 on
Darwin CD33/88
tie with
SP 1500 on USGS
L5-82-5P Line 12
WD 5725m
8
9
seconds (TWT)
5km
1400Z/147
1430Z/147
1500Z/147
1530Z/147
1600Z/147

SITE: LG-7 PRIORITY: 1

POSITION: 18°29.9'S
177°17.0'W

WATER DEPTH: 2913 m SEDIMENT THICKNESS: 100 m

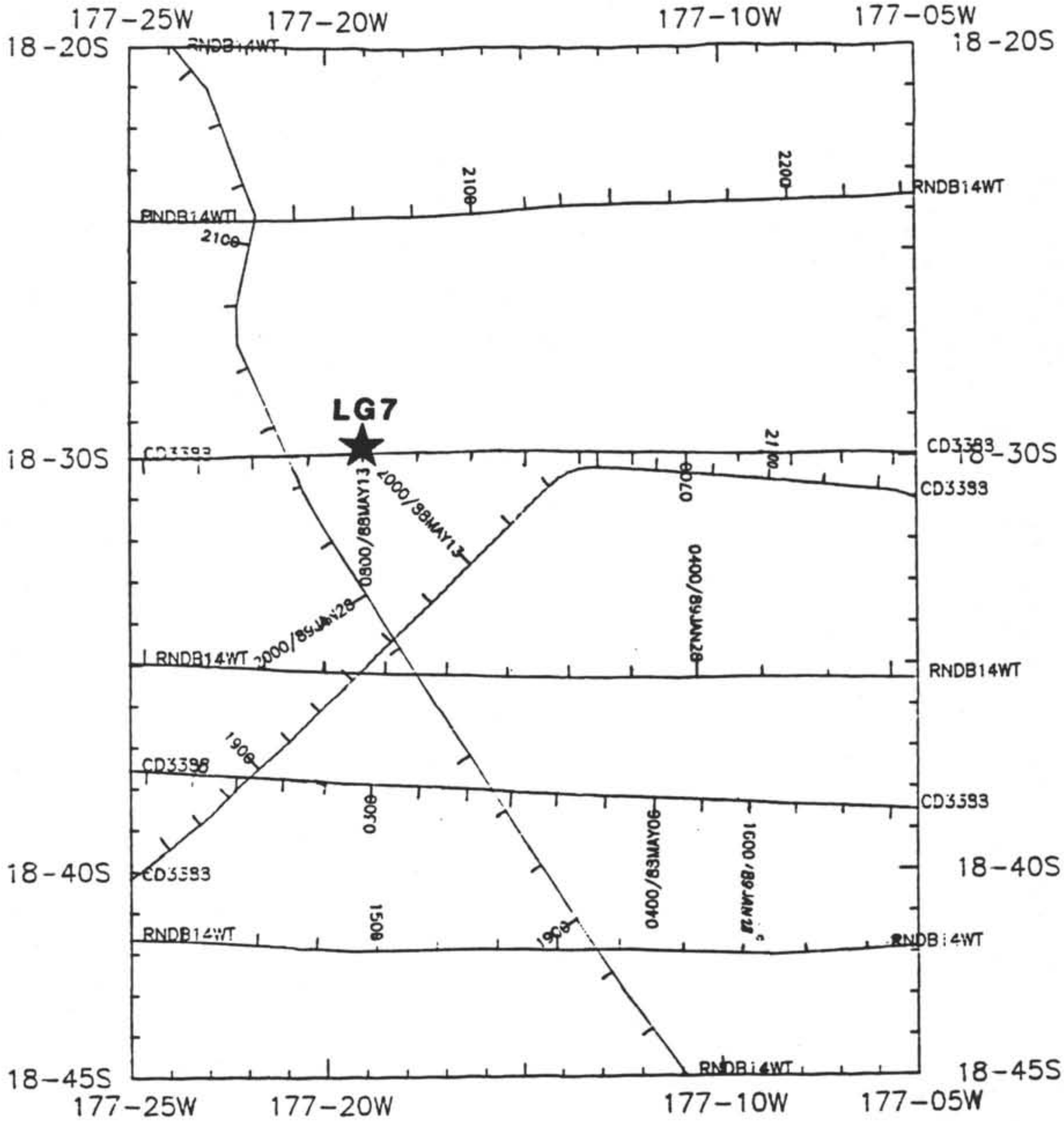
PROPOSED DRILLING PROGRAM: Hole A: APC to 100 mbsf. Hole B: RCB to 150 mbsf (or to bit destruction), and log hole.

SEISMIC RECORD: *Charles Darwin* cruise 33, 0745Z/134. Flanking lines of CD 33 2000Z/134 and *T. Washington* cruise RNDB14, 2010Z/28 Jan 89.

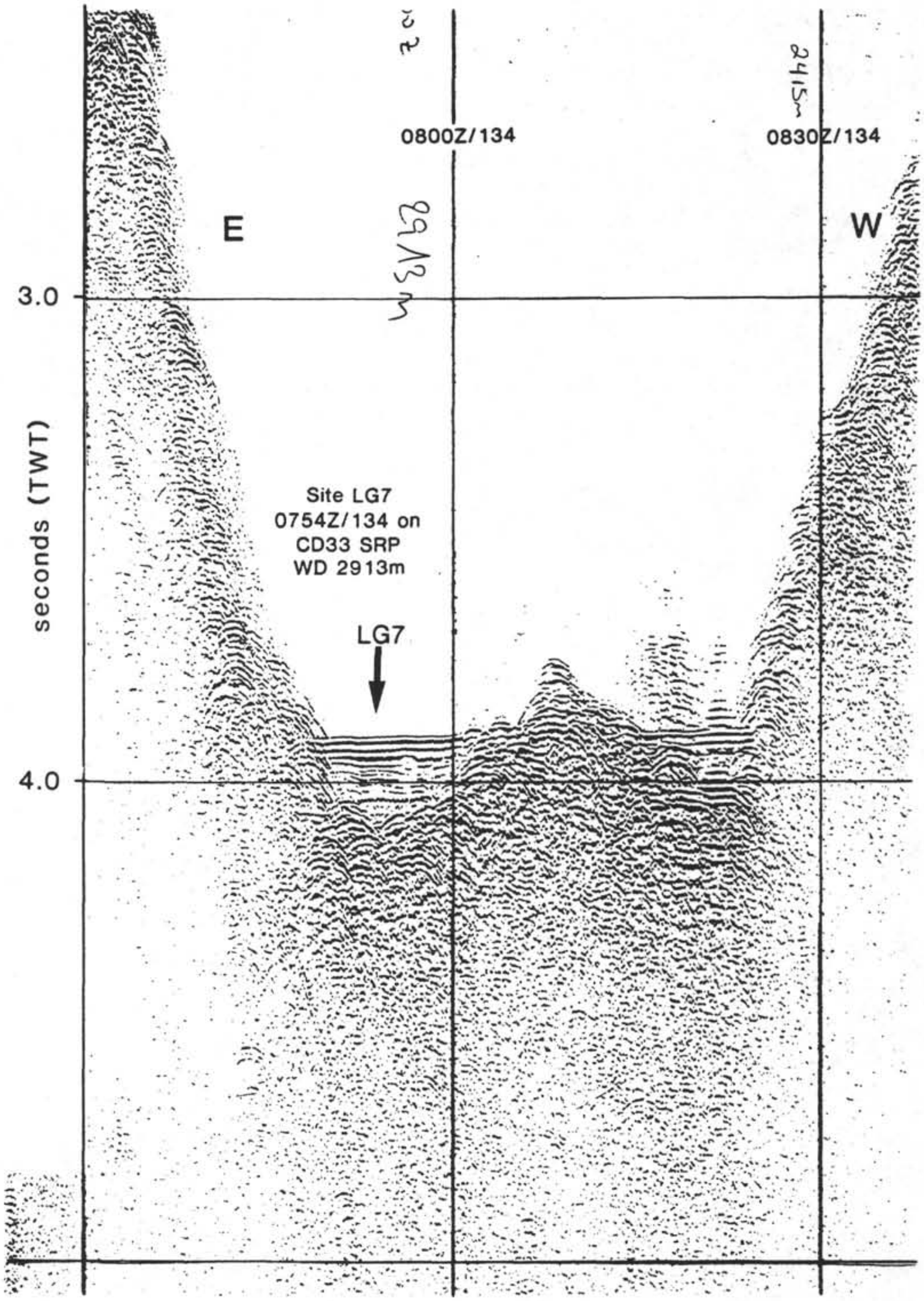
LOGGING: Standard Schlumberger logging, dual laterolog, magnetometer/susceptibility, formation microscanner, borehole televiewer.

OBJECTIVES: Science objectives are similar to those of LG-2, with the specific goals of assessing the nature and extent of hydrothermal activity, metallogenesis, and igneous basement rock chemistry. These data will be used for comparison with the petrology of site LG-2 and the axial ridge neovolcanic zone.

NATURE OF SEDIMENT/ROCKS ANTICIPATED: Calcareous ooze with pumice and ash interbeds overlying basalt.




ODP Site LG7
Scale: 16in/degree


0800Z/134
0830Z/134
E
W
3.0
4.0
seconds (TWT)
Site LG7
0754Z/134 on
CD33 SRP
WD 2913m
LG7

SITE: LG-9 PRIORITY: 2

POSITION: 20°07.6'S
176°42.8'W

WATER DEPTH: 2576 m SEDIMENT THICKNESS: ~300 m

PROPOSED DRILLING PROGRAM: Hole A: APC to 150 mbsf, XCB to 300 mbsf. Hole B: RCB to 350 mbsf (50 m into basement), log hole.

SEISMIC RECORD: *Charles Darwin* cruise CD33, 1820Z/130.

LOGGING: Standard Schlumberger logging, dual laterolog, magnetometer/susceptibility, formation microscanner, borehole televiewer.

OBJECTIVES: Overall objectives are the same as for LG-2 and LG-7. This site is believed to be on relatively young crust that formed from a different magma system-spreading center than that which presently forms the axial ridge at a propagating rift ~10 km east of these sites. Sites LG-9 and LG-9A will test the hypothesis that there has been a ridge jump and that different magma cells were involved in generation of the adjacent ridge segments.

NATURE OF SEDIMENT/ROCKS ANTICIPATED: Sediments are expected to be mixed carbonate ooze and volcaniclastics. Basement is expected to be pillows and flows of basalt with a variable extent of alteration.

SITE: LG-9A PRIORITY: 2

POSITION: 20°50.0'S
176°51.5'W

WATER DEPTH: 2285 m SEDIMENT THICKNESS: ~300 m

PROPOSED DRILLING PROGRAM: Hole A: APC to 150 mbsf, XCB to 300 mbsf. Hole B: RCB to 350 mbsf (50 m into basement), log hole.

SEISMIC RECORD: *Charles Darwin* cruise 33, 1040Z/145, tie with CD 33 0435Z/145.

LOGGING: Standard Schlumberger logging, dual laterolog, magnetometer/susceptibility, formation microscanner, borehole televiewer.

OBJECTIVES: Overall objectives are the same as for LG-2 and LG-7. This site is believed to be on relatively young crust that formed from a different magma system-spreading center than that which presently forms the axial ridge at a propagating rift ~10 km east of these sites. Sites LG-9 and LG-9A will test the hypothesis that there has been a ridge jump and that different magma cells were involved in generation of the adjacent ridge segments.

NATURE OF SEDIMENT/ROCKS ANTICIPATED: Sediments are expected to be mixed carbonate ooze and volcaniclastics. Basement is expected to be pillows and flows of basalt with variable extent of alteration.

SITE: LG-10 PRIORITY: 1

POSITION: 20°05.1'S
176°34.3'W
(Territorial waters of Tonga)

WATER DEPTH: 1910 m SEDIMENT THICKNESS: 100 m

PROPOSED DRILLING PROGRAM: Hole A: APC/XCB to 100 mbsf. Hole B: RCB to 150 mbsf, log hole. Hole C: set reentry cone, RCB to 300 mbsf, log basement.

SEISMIC RECORD: *Charles Darwin* cruise 33, 1720Z/130 and *T. Washington* cruise ROUNDABOUT 14, 0700Z/31 Jan 89.

LOGGING: Standard Schlumberger logging, dual laterolog, magnetometer/susceptibility, formation microscanner, drill-stem packer test of basement.

OBJECTIVES: Overall objectives are the same as for LG-2 and LG-7. This site is believed to be on relatively young crust that formed from a different magma system/spreading center than that which presently forms the axial ridge at a propagating rift ~10 km east of this site. LG-10 will test the hypothesis that there has been a ridge jump and that different magma cells were involved in generation of the adjacent ridge segments. In addition to the same types of logging data that will be collected at LG-2 and LG-7, a drill-stem packer test will be done here to assess permeability in young backarc crust.

NATURE OF SEDIMENT/ROCKS ANTICIPATED: Calcareous oozes with minor pumice; basement likely basalt.

SITE: LG-10A PRIORITY: 2

POSITION: 20°48.7'S
176°38.0'W

WATER DEPTH: 2385 m SEDIMENT THICKNESS: 100 m

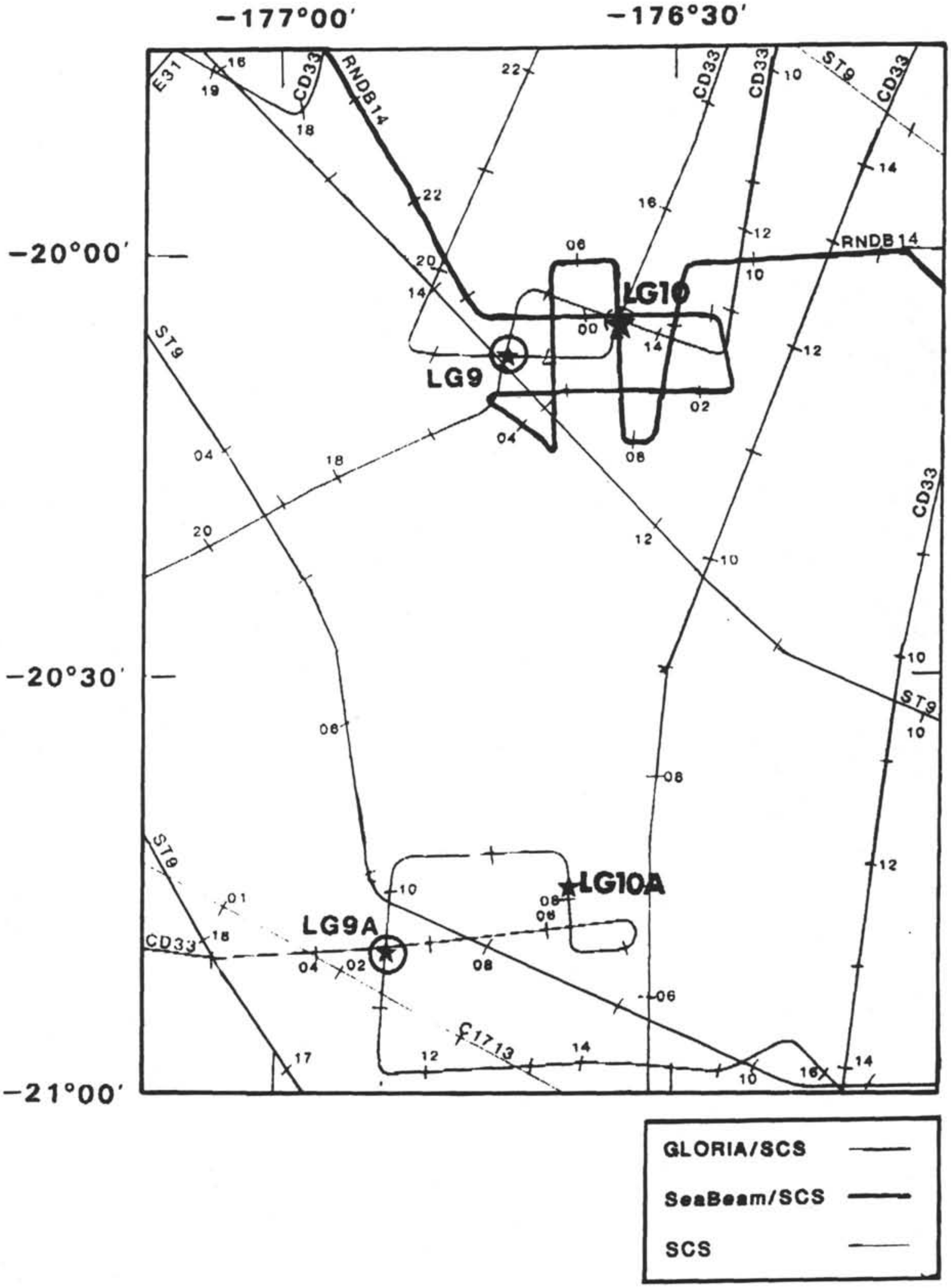
PROPOSED DRILLING PROGRAM: APC/XCB to 100 mbsf. Hole B: RCB to 150 mbsf, log hole. Hole C: set reentry cone, RCB to 300 mbsf, log basement.

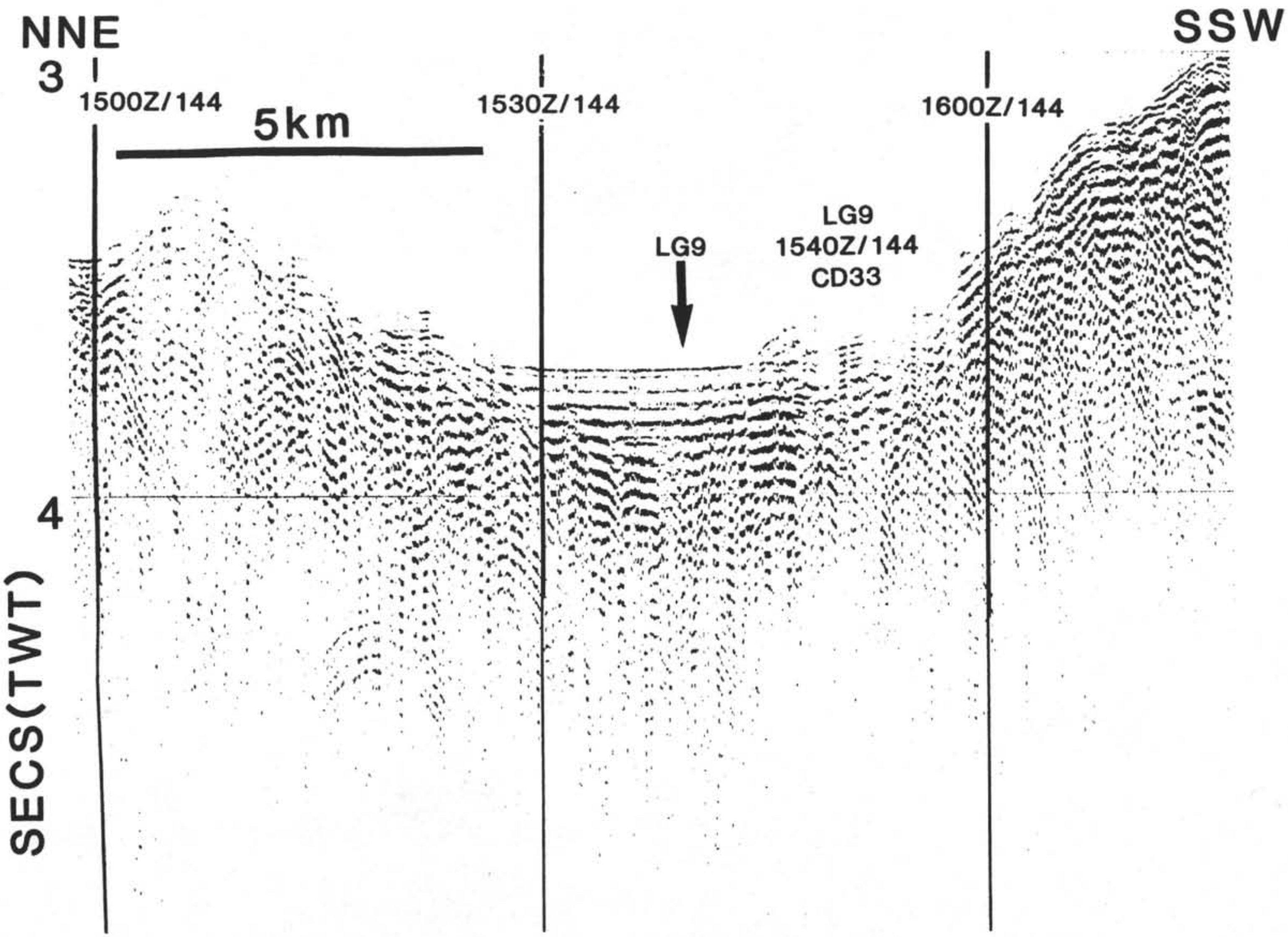
SEISMIC RECORD: *Charles Darwin* cruise 33, 0610Z/145 and cross line CD33 0748Z/145.

LOGGING: Standard Schlumberger logging, dual laterolog, magnetometer/susceptibility, formation microscanner, drill-stem packer test of basement.

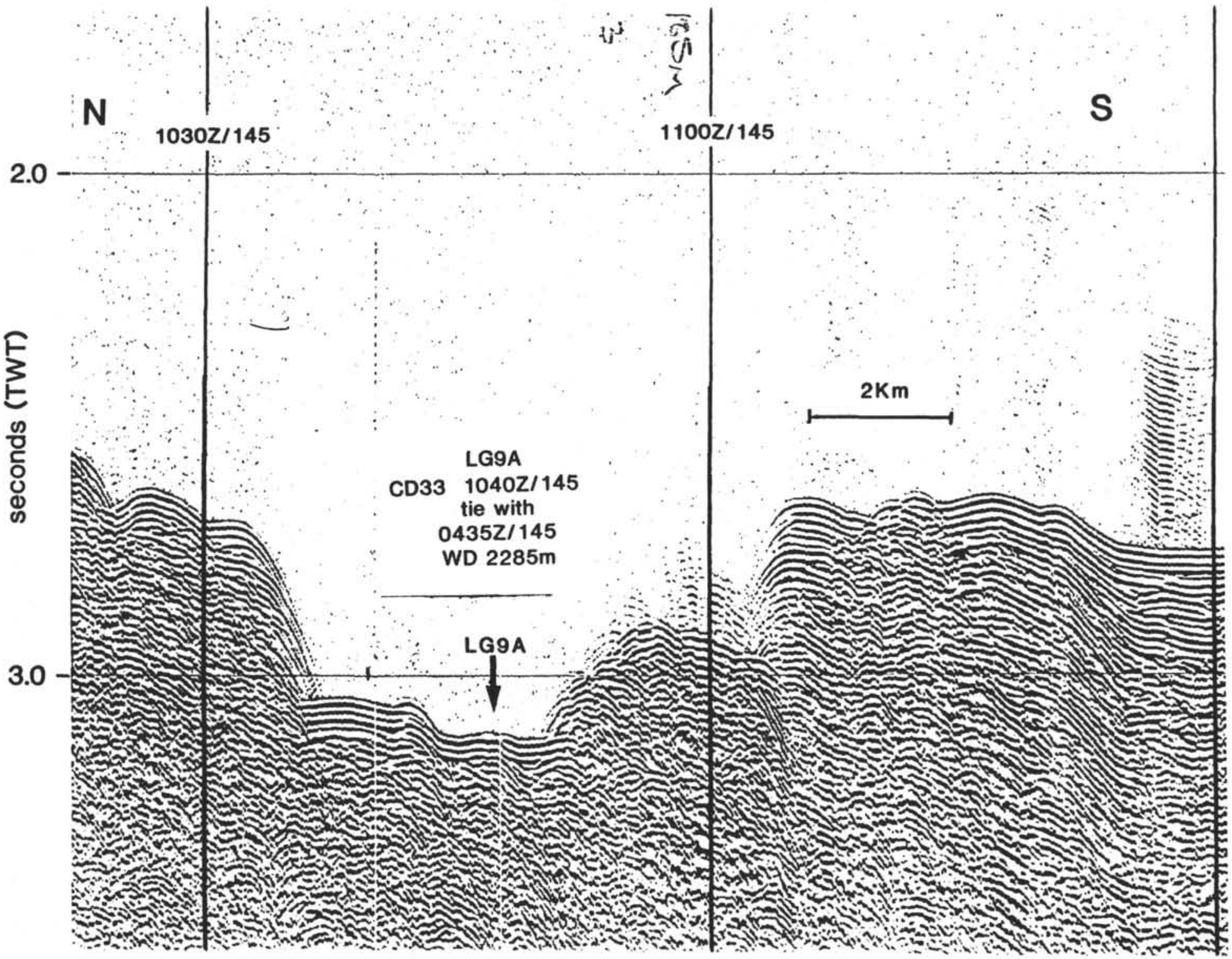
OBJECTIVES: Overall objectives are the same as for LG-2 and LG-7. This site is believed to be on relatively young crust that formed from a different magma system/spreading center than that which presently forms the axial ridge at a propagating rift ~10 km east of this site. LG-10A will test the hypothesis that there has been a ridge jump and that different magma cells were involved in generation of the adjacent ridge segments. In addition to the same types of logging data that will be collected at LG-2 and LG-7, a drill-stem packer test will be done here to assess permeability in young backarc crust.

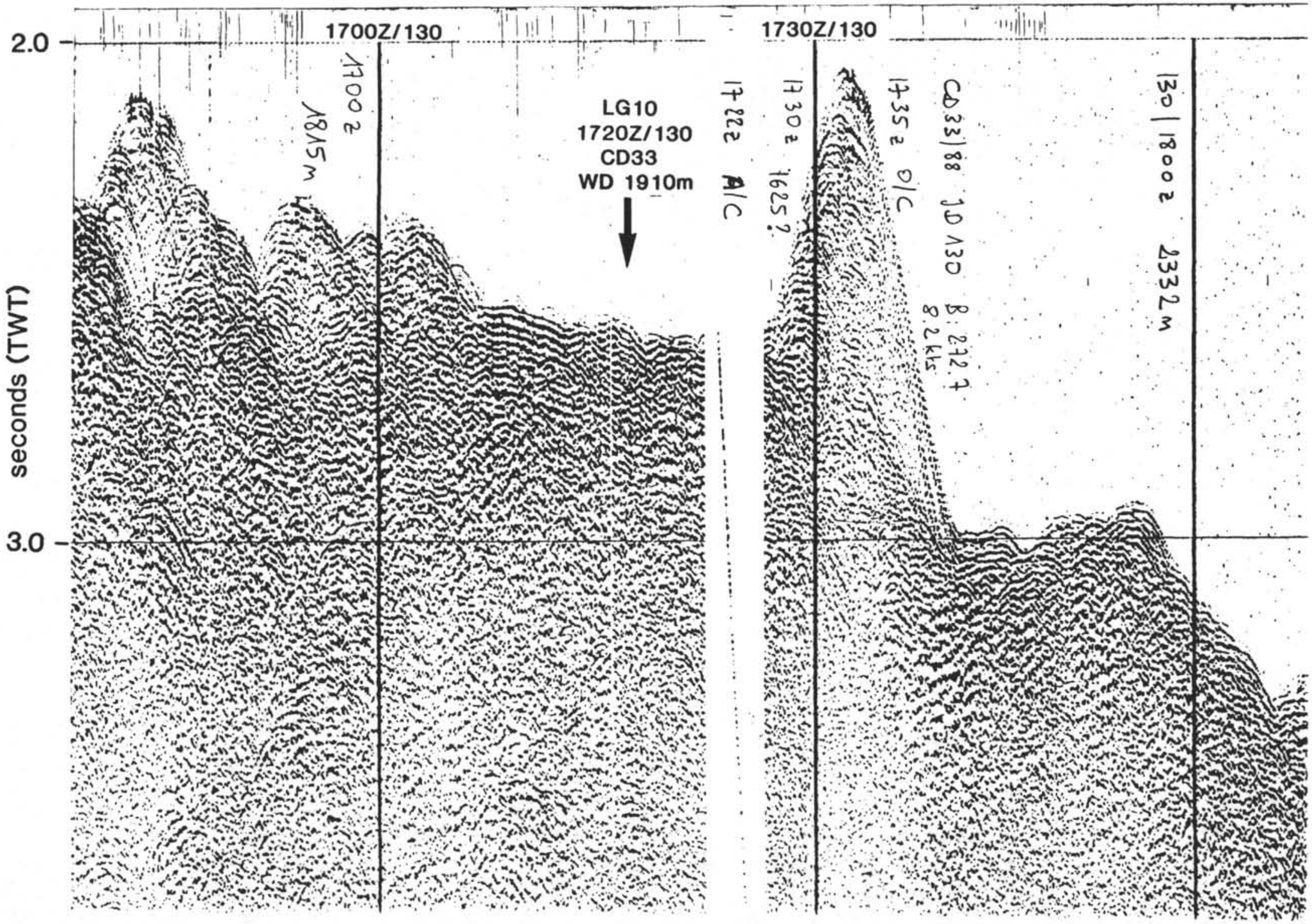
NATURE OF SEDIMENT/ROCKS ANTICIPATED: Calcareous oozes with minor pumice; basement likely basalt.

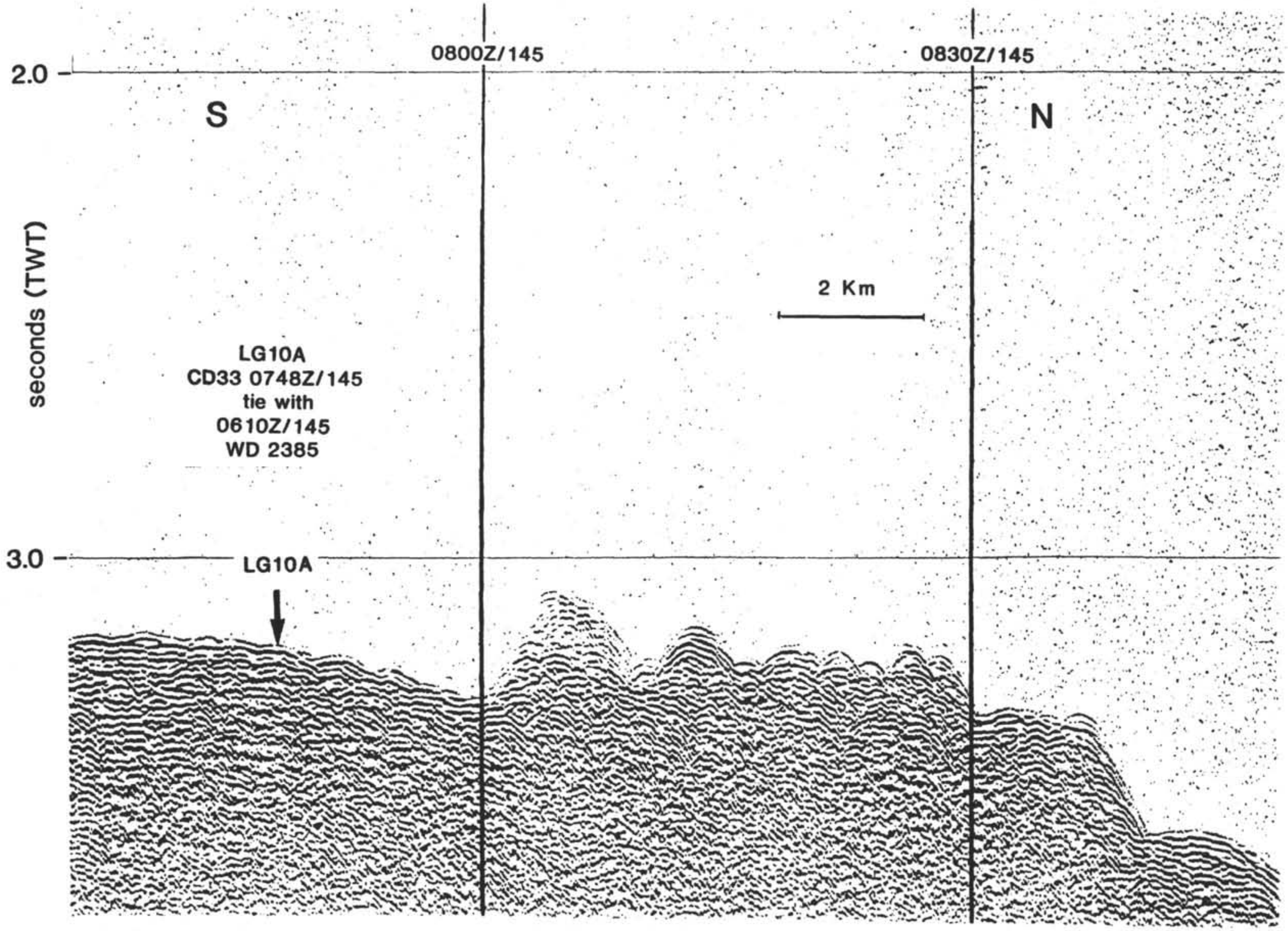

-177°00'
-176°30'
-20°00'
-20°30'
-21°00'
LG9
LG10
LG9A
LG10A
RNDB14
CD33
ST9
E31
C1713
GLORIA/SCS
SeaBeam/SCS
SCS

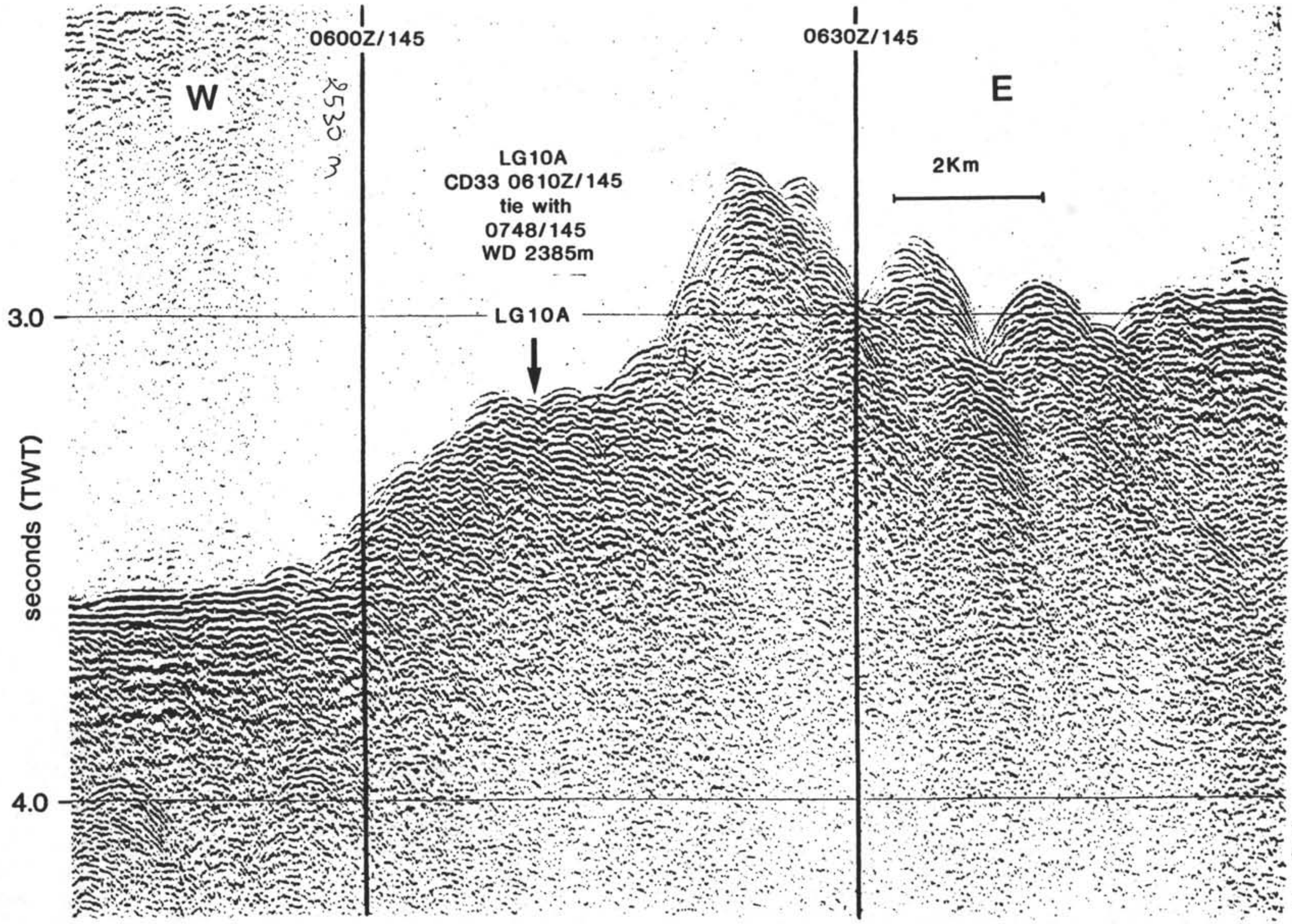

NNE
SSW
3
1500Z/144
5km
1530Z/144
1600Z/144
LG9
1540Z/144
CD33
LG9
4
SECS(TWT)

LG9


N
S
1030Z/145
1100Z/145
2.0
3.0
seconds (TWT)
2Km
LG9A
CD33 1040Z/145
tie with
0435Z/145
WD 2285m
LG9A


2.0
3.0
seconds (TWT)
1700Z/130
1730Z/130
LG10
1720Z/130
CD33
WD 1910m


0800Z/145
0830Z/145
2.0
3.0
S
N
seconds (TWT)
2 Km
LG10A
CD33 0748Z/145
tie with
0610Z/145
WD 2385
LG10A



0600Z/145
0630Z/145
W
E
2530 m
LG10A
CD33 0610Z/145
tie with
0748/145
WD 2385m
2Km
3.0
LG10A
seconds (TWT)
4.0

# OCEAN DRILLING PROGRAM
# LEG 135 SCIENTIFIC PARTICIPANTS

Co-Chief Scientist:

James Hawkins
Scripps Institution of Oceanography, A-020
University of California, San Diego
La Jolla, CA 92093

Co-Chief Scientist:

Lindsay M. Parson
Institute of Oceanographic Sciences
Brook Road, Wormley
Godalming, Surrey GU8 5UB
United Kingdom

Staff Scientist/Igneous Petrologist:

James Allan
Ocean Drilling Program
1000 Discovery Drive
Texas A&M Research Park
College Station, TX 77845-9547

Sedimentologist:

Ulrich Bednarz
Ruhr-Universität Bochum
Fakultät für Mineralogie
Universitätstrasse 150
Postfach 102148
4630 Bochum 1
Federal Republic of Germany

Sedimentologist:

Reidulv Bøe
Geological Survey of Norway
P.O. Box 3006 - Lade
N-7002 Trondheim
Norway

Sedimentologist:

Peter Cawood
Department of Earth Sciences
Memorial University
St. John's Newfoundland
Canada A1B 3X5

Sedimentologist:

Peter Clift
Grant Institute
Department of Geology and Geophysics
West Mains Road
Edinburgh, EH9 3JW
United Kingdom

Sedimentologist:

Richard A. Hodkinson
Marine Mineral Resources Programme
Department of Geology

| | |
|---|---|
| | Imperial College, Royal School of Mines<br>Prince Consort Road<br>London SW7 2BP<br>United Kingdom |
| Sedimentologist: | Cristelle E. Pratt<br>Mineral Resources Department<br>Private Mail Bag<br>Suva, Fiji |
| Sedimentologist/Phys. Props. Specialist: | Saimone P. Helu<br>Ministry of Lands, Surveys and Natural Resources<br>P. O. Box 5<br>Nukualofa<br>Tonga |
| Sedimentologist: | Jaquelyn K. Ledbetter<br>University of Tulsa<br>600 S. College<br>Tulsa, OK 74104 |
| Structural Geologist/Logging Scientist: | Chris MacLeod<br>Department of Earth Sciences<br>The Open University<br>Walton Hall<br>Milton Keynes MK7 6AA<br>United Kingdom |
| Phys. Props. Specialist/Geophysicist/ Logging Scientist: | Terry Bruns<br>U.S. Geological Survey<br>Pacific Marine Geology<br>3475 Deer Creek Road<br>Palo Alto, CA 94304 |
| Phys. Props. Specialist/Geophysicist/ Logging Scientist: | Andrew J. Stevenson<br>U.S. Geological Survey<br>Pacific Marine Geology<br>3475 Deer Creek Road<br>Palo Alto, CA 94304 |
| Paleontologist (nannofossils): | Paula J. Quinterno<br>U.S. Geological Survey, MS 999<br>345 Middlefield Road<br>Menlo Park, CA 94025 |
| Paleontologist (nannofossils): | Michael J. Styzen<br>Shell Offshore, Inc.<br>P.O. Box 61933<br>New Orleans, LA 70161 |

| | |
|---|---|
| Paleontologist (foraminifers): | George C. H. Chaproniere<br>Bureau of Mineral Resources<br>Division of Marine Geosciences<br>GPO Box 378<br>Canberra, 2601<br>Australia |
| Paleontologist (foraminifers): | Hiroshi Nishi<br>Department of Earth Sciences<br>Faculty of Science<br>Yamagata University<br>Yamagata, 990<br>Japan |
| Inorganic Geochemist: | Gerald Blanc<br>Centre de Géochimie de la Surface<br>Institut de Géologie<br>1, rue de Blessig<br>67084 Strasbourg Cedex<br>France |
| Organic Geochemist: | Martin Fowler<br>Geological Survey of Canada<br>Institute of Sedimentary & Petroleum Geology<br>3033 33rd St. NW<br>Calgary, Alberta T2L 2A7<br>Canada |
| Igneous Petrologist: | Sherman H. Bloomer<br>Department of Geology<br>Boston University<br>675 Commonwealth Avenue<br>Boston, MA 02215 |
| Igneous Petrologist: | Wilfred Bryan<br>Woods Hole Oceanographic Institution<br>Woods Hole, MA 02543 |
| Igneous Petrologist: | Anthony Ewart<br>Dept. of Geology & Mineralogy<br>The University of Queensland<br>St. Lucia, Queensland 4067<br>Australia |
| Igneous Petrologist: | Janet M. Hergt<br>The Open University<br>Walton Hall<br>Milton Keynes MK7 6AA<br>United Kingdom |

| | |
|---|---|
| Igneous Petrologist: | Kristen Nilsson<br>Scripps Institution of Oceanography, A-008<br>University of California, San Diego<br>La Jolla, CA 92093 |
| Sulfide/Alteration Petrologist: | Dietmar Schöps<br>Institut für Mineralogie und Lagerstattenlehre<br>RWTH Aachen<br>Wullnerstr. 2<br>D-5100 Aachen, West Germany |
| Paleomagnetist: | Will Sager<br>Department of Oceanography<br>Texas A&M University<br>College Station, TX 77843 |
| Paleomagnetist: | Niels Abrahamsen<br>Laboratory of Geophysics<br>Geological Institute<br>Finlandsgade 8<br>DK-8200 Aarhus N, Denmark |
| LDGO Logging Scientist: | TO BE NAMED |
| LDGO Logging Technician: | TO BE NAMED |

## OPERATIONS AND TECHNICAL PERSONNEL

| | |
|---|---|
| Operations Superintendent: | Gene Pollard<br>Ocean Drilling Program<br>1000 Discovery Drive<br>Texas A&M Univ. Research Park<br>College Station, TX 77845-9547 |
| Laboratory Officer: | Brad Julson<br>Ocean Drilling Program<br>1000 Discovery Drive<br>Texas A&M Univ. Research Park<br>College Station, TX 77845-9547 |
| Assistant Lab Officer: | Joe Powers<br>Ocean Drilling Program<br>1000 Discovery Drive<br>Texas A&M Univ. Research Park<br>College Station, TX 77845-9547 |
| Yeoperson: | Jo Claesgens<br>Ocean Drilling Program<br>1000 Discovery Drive<br>Texas A&M Univ. Research Park<br>College Station, TX 77845-9547 |

| | |
|---|---|
| Photographer: | John Tenison<br>Ocean Drilling Program<br>1000 Discovery Drive<br>Texas A&M Univ. Research Park<br>College Station, TX 77845-9547 |
| Chemistry Technician: | Joe DeMorett<br>Ocean Drilling Program<br>1000 Discovery Drive<br>Texas A&M Univ. Research Park<br>College Station, TX 77845-9547 |
| Chemistry Technician: | Scott Chaffey<br>Ocean Drilling Program<br>1000 Discovery Drive<br>Texas A&M Univ. Research Park<br>College Station, TX 77845-9547 |
| Electronics Technician: | Jim Briggs<br>Ocean Drilling Program<br>1000 Discovery Drive<br>Texas A&M Univ. Research Park<br>College Station, TX 77845-9547 |
| Electronics Technician: | Roger Ball<br>Ocean Drilling Program<br>1000 Discovery Drive<br>Texas A&M Univ. Research Park<br>College Station, TX 77845-9547 |
| Electronics Technician: | Eric Meissner<br>Ocean Drilling Program<br>1000 Discovery Drive<br>Texas A&M Univ. Research Park<br>College Station, TX 77845-9547 |
| Curatorial Representative: | Gretchen Hampt<br>Ocean Drilling Program<br>1000 Discovery Drive<br>Texas A&M Univ. Research Park<br>College Station, TX 77845-9547 |
| Computer System Manager: | John Eastlund<br>Ocean Drilling Program<br>1000 Discovery Drive<br>Texas A&M Univ. Research Park<br>College Station, TX 77845-9547 |

Marine Technician: Daniel Bontempo
Ocean Drilling Program
1000 Discovery Drive
Texas A&M Univ. Research Park
College Station, TX 77845-9547

Marine Technician: Norman Haywood
Ocean Drilling Program
1000 Discovery Drive
Texas A&M Univ. Research Park
College Station, TX 77845-9547

Marine Technician: "Kuro" Kuroki
Ocean Drilling Program
1000 Discovery Drive
Texas A&M Univ. Research Park
College Station, TX 77845-9547

Marine Technician: Mike Moore
Ocean Drilling Program
1000 Discovery Drive
Texas A&M Univ. Research Park
College Station, TX 77845-9547

Marine Technician: Joan Perry
Ocean Drilling Program
1000 Discovery Drive
Texas A&M Univ. Research Park
College Station, TX 77845-9547

Marine Technician: TO BE NAMED
Ocean Drilling Program
1000 Discovery Drive
Texas A&M Univ. Research Park
College Station, TX 77845-9547

Marine Technician: TO BE NAMED
Ocean Drilling Program
1000 Discovery Drive
Texas A&M Univ. Research Park
College Station, TX 77845-9547

Schlumberger Engineer: Brian Davis
Schlumberger Corpus Christi
1745 North Padre Island Drive
Corpus Christi, Texas 78408