BULLETIN OF THE EARTHQUAKE
RESEARCH INSTITUTE
UNIVERSITY OF TOKYO
Vol. 64 (1989) pp. 119-131

Report on DELP 1987 Cruises in the Ogasawara Area

Part I: General Outline

JAPANESE DELP RESEARCH GROUP ON BACK-ARC BASINS

(Received April 28, 1989)

Abstract

Late in the fall of 1987, as a part of the Japanese National Research Program (DELP/Dynamics and Evolution of the Lithosphere Program: Japanese title of ILP) a geophysical and geological research cruise (DELP-87 cruise by two vessels) was carried out in the western margin of the Pacific and the Ogasawara (Bonin) Trough area, one of the back-arc basins in the western part of the Pacific. It is suggested through the present and past studies that the trough has been formed as a result of differential rifting and subsequent opening of the Parece Vela and Shikoku Basins in the middle Tertiary. The crustal structure of the trough is basically similar to those of other part of the Izu-Ogasawara system but it represents a consequence of tectonic stretching. Therefore, the horizontal stress field of the trough area between ca. 50 and 20 Ma may have been extensional. A conspicuous feature of the world's highest gravity anomaly associated with the existence of a large Boninite mass around the Ogasawara Ridge in the eastern part of the trough must be supported by some dynamic uplifting force if not a compressive horizontal stress field.

1. Introduction

To the east of the Ogasawara Trough, the Pacific Plate (PAC) is subducting underneath the Philippine Sea Plate along the Izu-Ogasawara Trench system (IOT: index map of Fig. 1). The Pacific Plate to the east of the Ogasawaras consists of oceanic lithosphere of Late Jurassic age, the oldest lithospheric fragment existing in the Pacific region. The Ogasawara Trough was formed in the Tertiary and has been inactive in the recent period. On the western flank of the Ogasawara Trough, however, there are at least four Quaternary volcanic islands obviously active in the recent

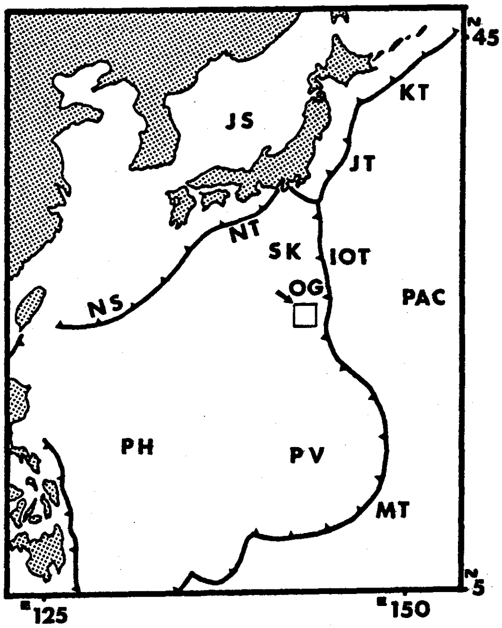
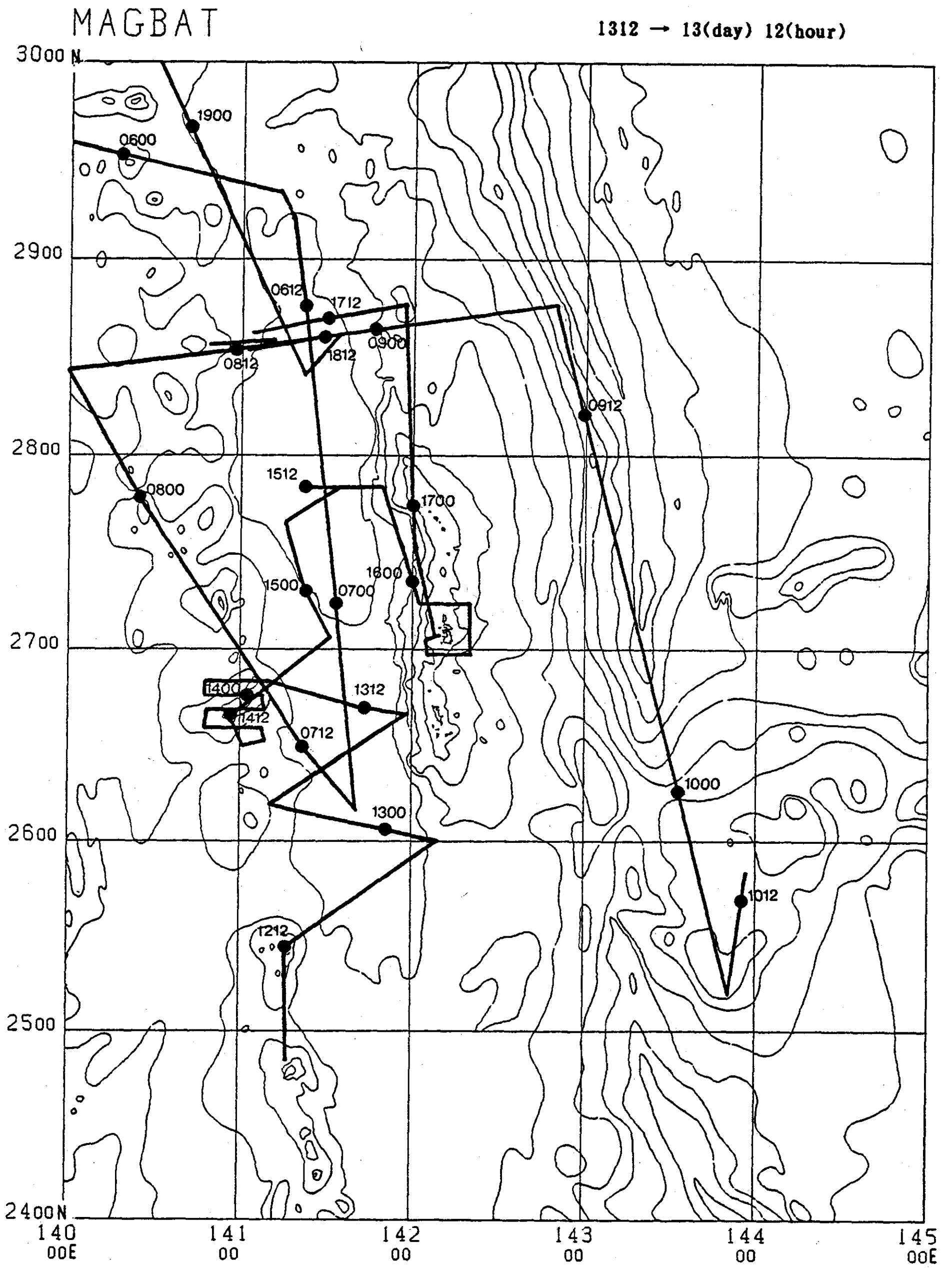


Fig. 1. An index map of the survey area and morphological units of surrounding regions. JS : Japan Sea, SK : Shikoku Basin, PH : Philippine Sea Basin, PV : Parece Vela Basin, KT : Kuril-Kamchatka Trench, JT : Japan Trench, IOT : Izu-Ogasawara Trench, MT : Mariana Trench, NT : Nankai Trough, NS : Nanseishoto Trench. Present survey of DELP 1987 was performed in OG : Ogasawara Trough and Ridge areas.

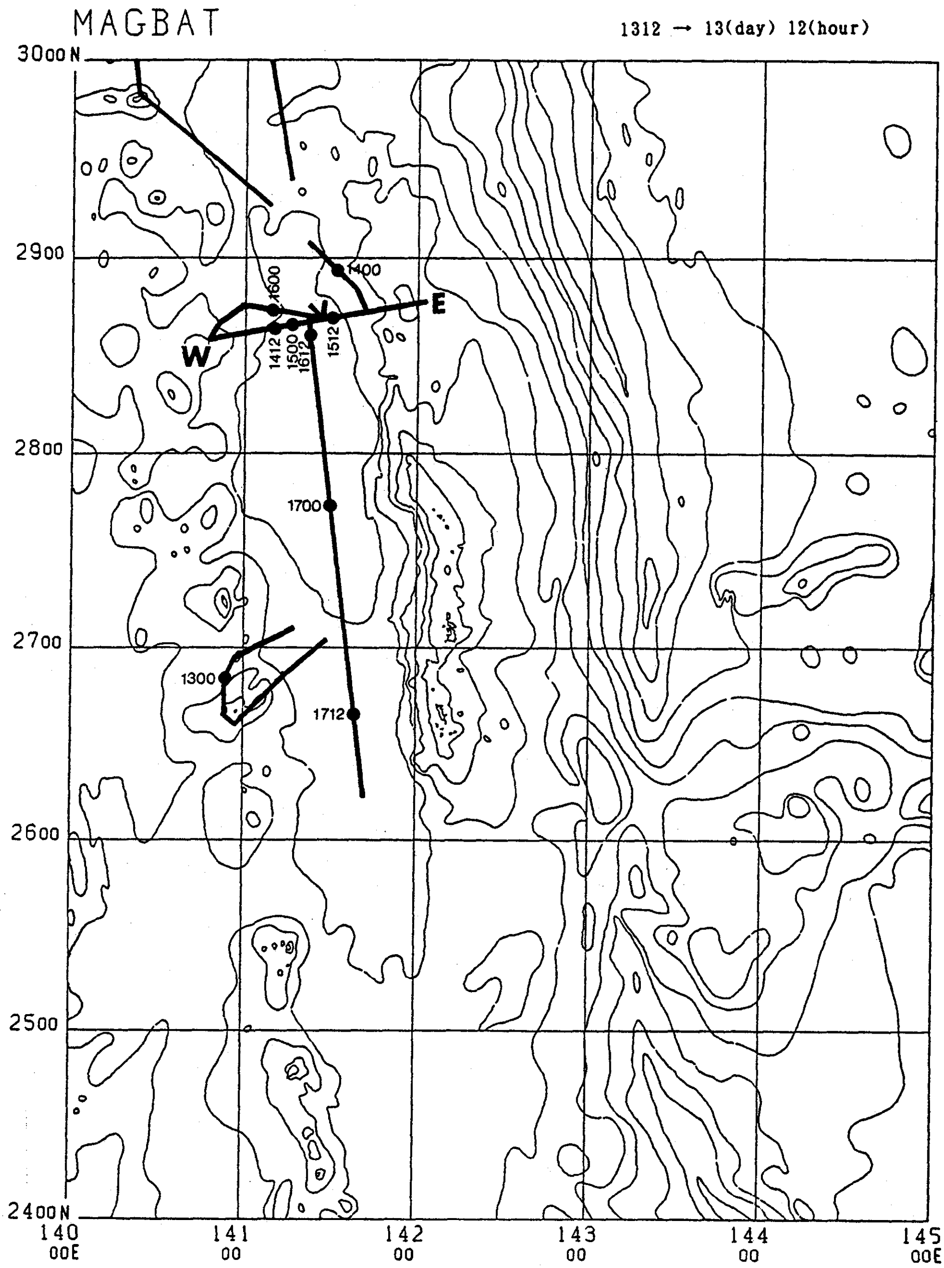
time. The area of detailed survey by the DELP-87 cruise is shown in Fig. 2a and 2b.

This area is characterized by the following features. 1 : Change of the distribution patterns in seismicity and features of the Wadati-Benioff zones between southern part and northern part of the Izu-Ogasawara Arcs bounded by the Ogasawara (Bonin). 2 : Low seismicity below the Ogasawara Trough (KATSUMATA and SYKES, 1969). 3 : Collision of a line of seamounts associated with a line of free air gravity anomaly trend apparently originated at the East Pacific Rise with the Izu-Ogasawara Trench at the southern part of the Ogasawara Trough (SMOOT, 1983 ; SEGAWA and MATSUMOTO, 1987). 4 : Conspicuous high free air and Bouguer gravity anomaly in the Ogasawara Ridge area. 5 : Southward dipping of negative free air gravity in spite of northward dipping of the bathymetric depths in the Ogasawara Trough (ISHIHARA *et al.*, 1981 ; HONZA and TAMAKI, 1985). 6 : Possible rifting of the Ogasawara Trough in the Tertiary era



(a)

Fig. 2. Survey lines and stations of DELP-87 cruise in the Ogasawara area by DELP research group on back-arc basins.
a: Track lines of Tokai-Daigaku-Maru Nisei, Tokai University.
b: Track lines of Wakashiomaru, Nippon Salvage Company.


MAGBAT
1312 → 13(day) 12(hour)
3000N
2900
2800
2700
2600
2500
2400N
140 00E
141 00
142 00
143 00
144 00
145 00E
1400
1600
E
W
1412
1500
1612
1512
1700
1300
1712

(b)

(HONZA and TAMAKI, 1985) and reactivation of back-arc system in the Quaternary era (TAMAKI *et al.*, 1981). 7: Conspicuous westerly deviation of a line of active volcanic islands to the west of the Ogasawara Trough compared to those along northern and southern parts of the Izu-Ogasawara system (VOLCANOLOGICAL SOCIETY OF JAPAN, 1971). 8: Higher local heat flow values on the western side of the Ogasawara Trough (VAQUIER *et al.*, 1966; MATSUBARA, 1981). 9: Oblique alignments of older and younger tectonic features along the back-arc area of the Izu-Ogasawara system (YUASA, 1983). All these features cannot be easily explained because of tectonic complexities of this region compared to other frontal arc and back-arc basin couples (KARIG and MOORE, 1975).

Seismic velocity structures of the lithosphere of the area including the Ogasawara Trough have been studied by several authors (HOTTA, 1970; LATRAILLE and HUSSONG, 1983; KARIG and RANKEN, 1983; BIBBEE *et al.*, 1980; AMBOS and HUSSONG, 1982; SINTON and HUSSONG, 1983; HUSSONG and SINTON, 1983; HAMBERGER *et al.*, 1983; KASAHARA *et al.*, 1985). Most extensive structural study across the Ogasawara Trough was achieved by HOTTA (1970) and it was shown that there exists a thick layer (ca. 5 km) of seismic P-wave velocity 5.39 km/s underneath the trough area. This suggests an accumulation of relatively low velocity materials either due to high temperature or thick sediment (or turbidites) beneath the trough.

2. Scientific Objectives

The scientific objectives of DELP-87 are to study the tectionic structure and evolution of the Ogasawara back-arc basin and to obtain insight into the deeper dynamics of the back-arc rifting and coupling between the upper of the presumably subducting lithosphere and the island-arc structure of the eastern side of the Philippine Sea Basin. The DELP-87 cruise comprised R/V Wakashio-maru, Nippon Salvage Company and Tokai-Daigaku-Maru Nisei (Junior), Tokai University. The latter was offered by courtesy of the Department of Oceanography, Tokai University to make a joint study with the DELP group. Scientists from six universities and institutions participated in the program. A part of the Seabeam mapping obtained recently by Japan Maritime Safety Agency (unpublished) was offered for integrated studies of the present program.

3. Cruise period

Cruise DELP-87 WAKASHIO (Wakashio-maru) and NISEI (Tokai-Daigaku-Maru Nisei; Junior Cruiser)

*** WAKASHIO

November 7, 1987. Departure from Chuo, Chiba

10–11 Deployment of OBS (Ocean Bottom Seismometer)

11–13 Explosions of small charge and Air-gun shooting

14–18 Multi-channel seismic profiling

20 Back to Chiba

7–20 Magnetic measurement all along steaming tracks

*** NISEI

November 4, 1987. Departure from Shimizu, Shizuoka

6–16 Single-channel seismic profiling, Detailed magnetic survey, Heat flow, Dredge haul, Gravity coring, Deployment of OBS

17–18 Recovery of OBS

21 Back to Shimizu

4–21 Magnetic measurement all along steaming tracks

4. Items of observation

1) 12KHz Precision Depth Recording
2) 3.5 KHz Depth Recording
3) Multi-channel Seismic Profiling
4) Single-channel Seismic Profiling
5) Structure by Ocean Bottom Seismometer
6) Geomagnetic Survey
   6)-1 Total force
   6)-2 Three-axis vector component
7) Heat Flow
8) Dredge Haul
9) Gravity Coring

5. Data filing and processing

1) Track positioning
2) Depth record (digitized) for whole track lines
3) Shot instance of large volume Airgun
4) Shot instance of explosions
5) Geomagnetic elements (Hx, Hy, Hz and F)
6) Seismic wave form (digitized)

6. Particpants

Earthquake Research Inst., Univ. Tokyo
S. NAGUMO and S. KORESAWA

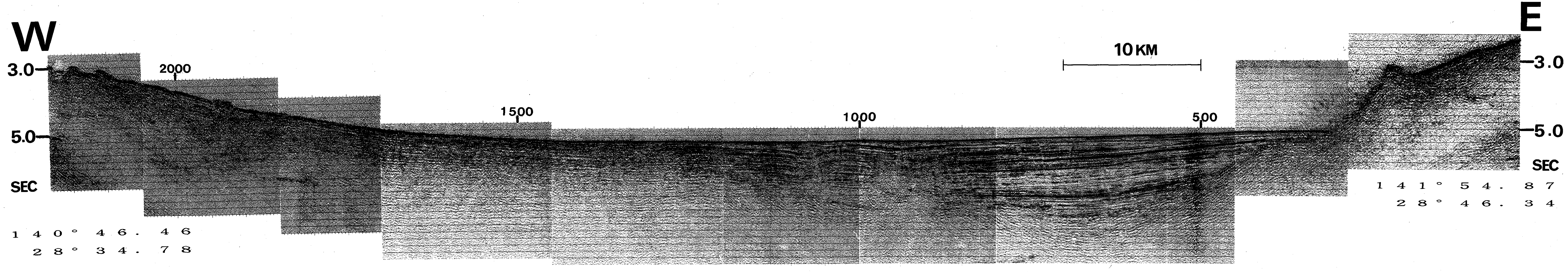
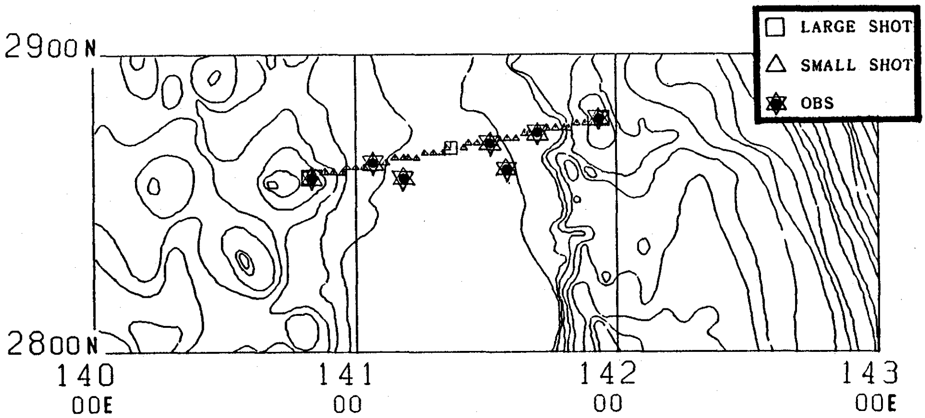


Fig. 3. Image of seismic reflection profiling digitally processed along the E-W seismic survey line of Fig. 2b (marked by W and E on both ends).

Ocean Research Inst., Univ. Tokyo
H. TOKUYAMA and T. PAAK
Observation Center for Prediction of Earthquakes and Volcanic Eruptions, Tohoku Univ.
A. NISHIZAWA and R. HINO
Department of Earth Sciences, Chiba Univ.
H. KINOSHITA, K. SUYEHIRO, S. ABE, Y. KASUMI, K. SUZUKI, Y. SHIMIZU, H. MIYATA, C. KITAHARA, T. OGISHIMA, Y. ONO, T. FUKUI, M. OGASAWARA, Y. AMAGASA, M. ISHIBASHI, S. SUZUKI and N. TAMAKI
Department of Oceanography, Tokai Univ.
M. ISHIKAWA, H. ISHIKAWA and H. BABA
Department of Earth Sciences, Kobe Univ.
N. ISEZAKI, H. INOKUCHI, T. OUCHI, A. KUBO, Y. INOUE, K. SUGIMOTO, H. ICHIKAWA and K. TAKAHASHI.

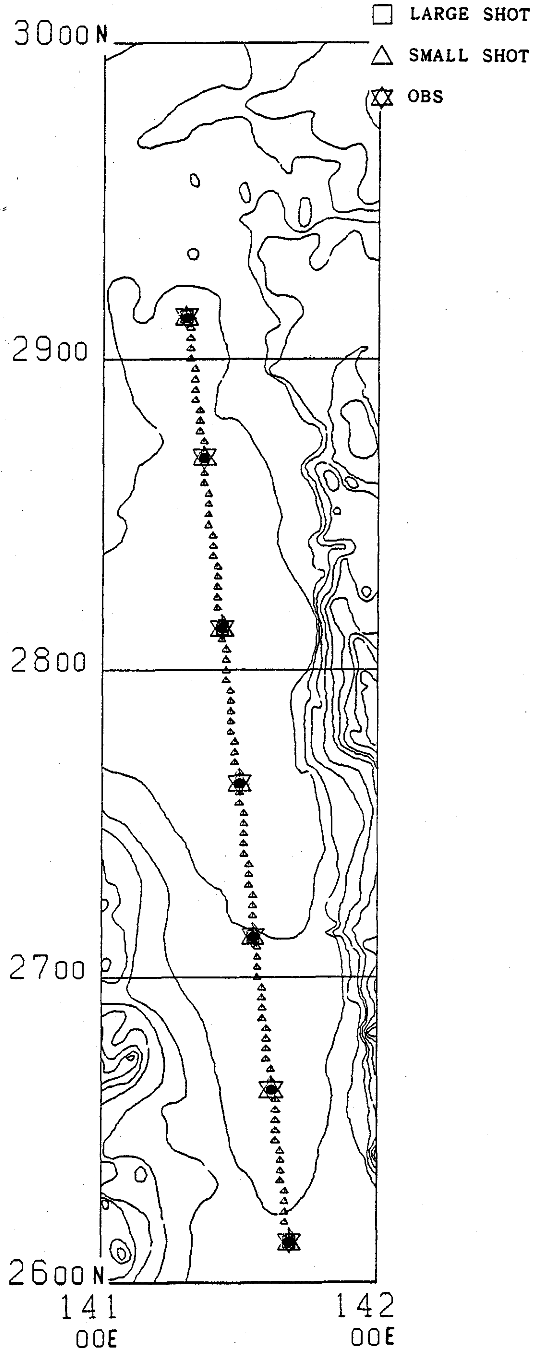
7. Main operations

Geophysical and geological surveys of the DELP-87 cruise were concentrated on seismic studies on the lithospheric and crustal structures as well as geomagnetic measurement of the area. Heat flow measurements were also attempted. Geomagnetic surveys were run by use of both three-



(a)

Fig. 4. Positions of OBS stations along the seismic survey line using explosives and shots from a large volume airgun. Volume of the airgun chamber was 24 liter. OBS: Ocean Bottom Seismographs, Large and Small shot: indicating dynamite charges as listed in the table of Part 4 of this issue.
a: along the E-W track line and b: along the N-S track line.



(b)

axis magnetometer and proton precession magnetometer. Dredge hauls of volcanic materials and gravity coring were achieved too.

Seismic study of the crustal structure of this area was one of the main themes of DELP-87 by use of explosives and air-gun as sound sources and ocean bottom seismographs (OBS) as sound receivers. An example of seismic reflection patterns along an east-west line is shown in Fig. 3; its interpretation is given Part II of this issue. Fifteen sets of OBS were deployed along two track lines of which 8 sets are offered from Earthquake Research Institute, 2 from Tohoku University, 3 from Chiba University and 2 from Tokai University. Position of the OBS stations are shown in Fig. 4. Total length of seismic survey track lines amounts to about 270 NM. Shooting by big and small charge explosives and big volume (24 liter) airgun array was run along the track lines. A number of small charge explosives were also used in cooperation with the big airgun shooting.

Three-axis magnetometers on board research vessels as well as proton precession magnetometers towed behind vessels were run through the entire periods of the present cruises.

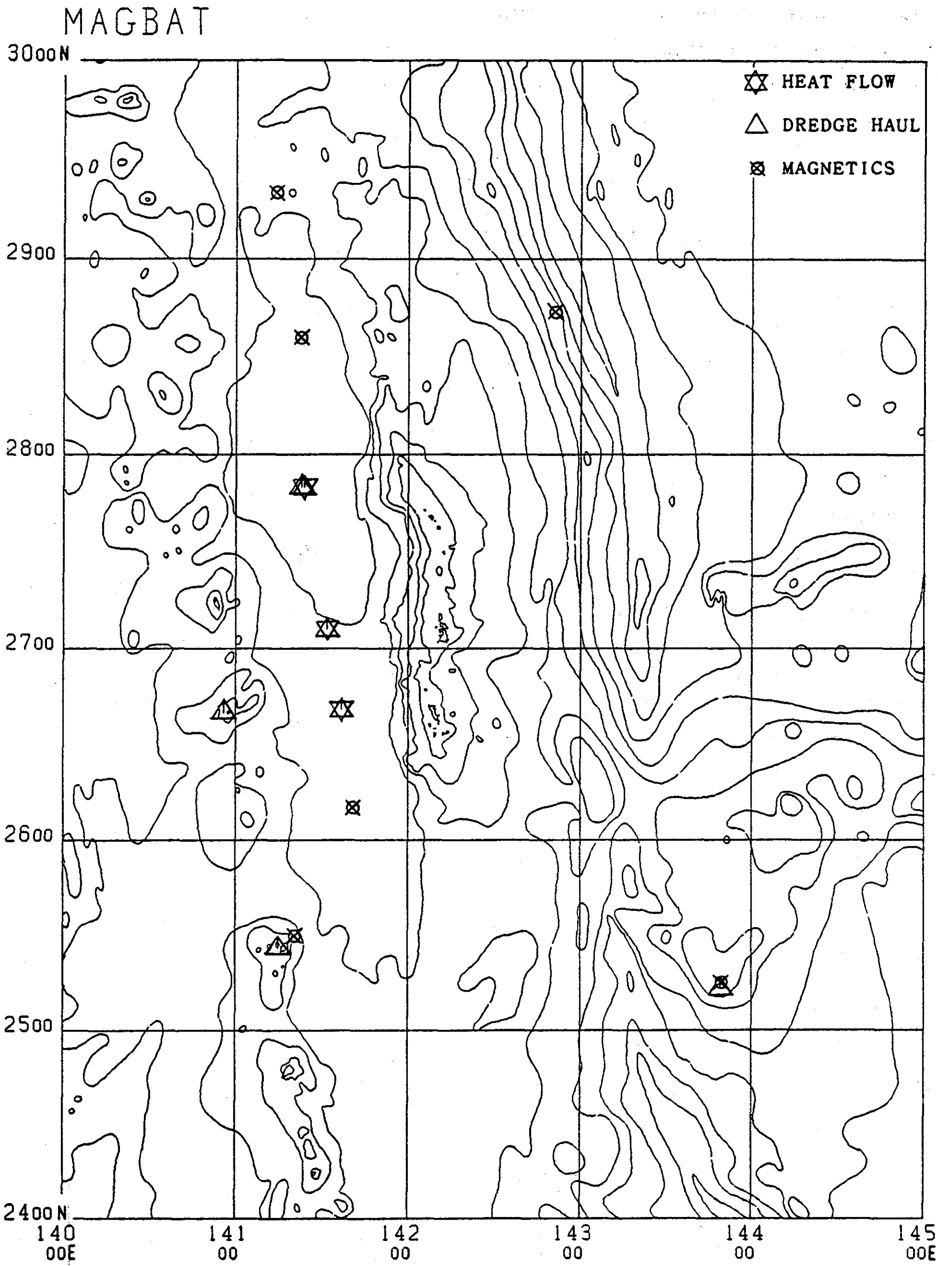


Fig. 5. Positions of stations for various measurements as well as sampling. Staions for heat flow, dredge haul and magnetic calibration (see text of Part 5 of this issue) are shown.

Magnetometer systems were calibrated, often on board, when the ship changed its latitudinal position considerably (Fig. 5). This measure was achieved on the assumption that there is a significant variation of magnetic field elements, mostly with change in latitudinal positions and the research vessels made of steel carry magnetizations, remanent and induced. Surveys were performed along the entire track lines as well as concentrated survey track lines around conspicuous seamounts. Heat flow measurements were run at 12 stations and dredge hauls were carried out at 7 stations as indicated in Fig. 5.

8. Main Results

Detailed studies of each item of observation are described in separate papers of this article. Some of the main results of the DELP-87 cruise are briefly summarized here.

1) The seismic reflection pattern is opaque in the western part but transparent and laminar in the eastern part of the Ogasawara Trough. Sediment basement interface in general dips southward in accordance with deepening of the negative free air gravity anomaly toward the south. Deepening of the acoustic basement toward the east and a thick sediment fill which is in direct contact with the basement formation of the Ogasawara Ridge suggests that the trough was formed by pull-apart tectonism.

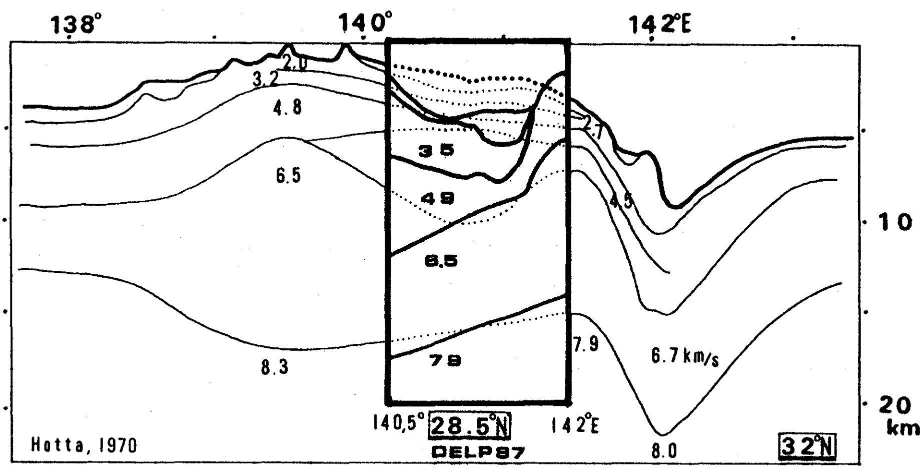


Fig. 6. Preliminary seismic structures of the upper part of the lithosphere of the Ogasawara Trough along the E-W seismic survey line of Fig. 2b embedded into the seismic structure along 32 degrees north, obtained by HOTTA (1970) for comparison of the structures of both areas. Further descriptions are given in Parts 3 and 4 of this issue.

This is also implied from the stepwise normal faults of the acoustic basement of the area associated with westward tilting of faulted blocks.

2) The Moho boundary appears to be at 15 km depth in good accordance with the structural model along 32 degrees North, about 400 kilometers north of the present survey area (HOTTA, 1970: Fig. 6).

3) There is an indication of a series of intrusions of valcanic dikes in the central axial part of the Ogasawara Trough.

4) Seamounts in the western flank of the trough are mostly of normal and homogeneous magnetization.

5) Chemical composition of the volcanics obtained from the submarine slope of one of the volcanic islands in the western side of the trough (Kita Iwo Jima and nearly islands) shows a bimodal feature. Two types of thoreiites, i. e., high alkali and low alkali thoreiites, coexist. They could have been caused either by premature mixing and segregation of magma sources or by basically different magma sources.

Acknowledgments

Participants of the DELP 1987 cruises are greatly indebted to crew members of both of the research vessels, Wakashio and Tokai-daigaku-maru Nisei, for their enthusiastic cooperation through the entire period of the presents survey. This program was mostly supported by a research grant for DELP from the Ministry of Education, Science and Culture (Monbusho) of Japan.

References

AMBOS, E. L. and D. M. HUSSONG, 1982, Crustal structure of the Mariana Trough, *J. Geophys. Res.*, **87**, 4005-4018.

BIBBEE, L. D., G. SHOR and R. LU, 1980, Inter-arc spreading in the Mariana Trough, *Marine Geol.*, **35**, 183-197.

HAMBERGER, M. W., R. K. KRADWELL, B. L. ISACKS and J. CHIU, 1983, A land-ocean bottom seismograph experiment in the Mariana forearc, *Bull. Seismol. Soc. America*, **73**, 1825-1834.

HONZA, E. and K. TAMAKI, 1985, The Bonin arc, in *The Ocean Basins and Margins*, **7A**, edit. Nairn, A. E. M., Stehli, F. G and Uyeda, S., 459-502.

HOTTA, H., 1970, A crustal section across the Izu-Ogasawara arc and trench, *J. Phys. Earth*, **18**, 125-141.

HUSSONG, D. M. and J. B. SINTON, 1983, Seismicity associated with back-arc crustal spreading in the Central Mariana Trough, in *Tectonic and Geologic Evolution of Southeast Asian Seas and Islands, Part 2*, edit. Hayes, D. E., *AGU, Geophys. Monogr.*, **27**, 217-235.

ISHIHARA, T., F. MURAKAMI, T. MIYAZAKI and K. NISHIMURA, 1981, Gravity survey, in *Geological Investigation of the Ogasawara (Bonin) and Northern Mariana Arcs,* *Cruise GH79-2, 3 and 4 by Geological Survey of Japan, Cruise rept.* No. 14, 45-78.

KARIG, D. and G.F. MOORE, 1975, Tectonic complexities in the Bonin arc system, *Tectonophys.*, 27, 97-118.

KARIG, D. and B. RANKEN, 1983, Marine geology of the forearc region Southern Mariana Island Arc, in *Tectonic and Geologic Evolution of Southeast Asian Seas and Islands, Part 2*, edit. Hayes, D.E., *AGU, Geophys. Monogr.*, 27, 266-279.

KASAHARA, J., NAGUMO, S., KORESAWA, S., OUCHI, T. and KINOSHITA, H., 1985, Seismic study by OBSH in the northern part of the Mariana Trough, *Preliminary Rept. Hakuho Maru Cruise KH84-1, Ocean Res. Inst. Univ. Tokyo*, 272-275.

KATSUMATA, M. and L. SYKES, 1969, Seismicity and tectonics of the western Pacific: Izu-Mariana-Caroline and Ryukyu-Taiwan Regions, *J. Geophys. Res.*, 74, 5923-5948.

LATRAILLE, S.L. and D.M. HUSSONG, 1983, Crustal structure across the Mariana Island Arc, in the Tectonic and geologic evolution of Southeast Asian Seas and Islands, Part 2, edit. Hayes, D.E., *AGU, Geophys. Monogr*, 27, 209-221.

MATSUBARA, Y., 1981, Heat flow measurements in the Bonin arc area, *Report on cruise GH79-3 of Geological Survey of Japan*, 130-135.

SEGAWA, J. and T. MATSUMOTO, 1987, Free air gravity anomaly of the world ocean as derived from satellite altimeter data, *Bull. Ocean Res. Inst., Univ. Tokyo*, No. 25, 1-122.

SINTON, J.B. and D.M. HUSSONG, 1983, Crustal structure of a short length transform fault in the Central Marianas, in *Tectonic and Geologic Evolution of Southeast Asian Sea and Islands*, Part 2, edit. Hayes, D.E., *AGU Geophys. Monogr.*, 27, 236-253.

SMOOT, N.C., 1983, Multi-beam surveys of the Michelson Ridge guyots: subduction and obduction, *Tectonophys.*, **99**, 363-380.

TAMAKI, K., E. INOUE, M. YUASA, M. TANAHASHI and E. HONZA, 1981, A probable occurrence of rifting in Ogasawara back-arc basin in Quaternary era, *Earth Monthly*, 3, 421-431, (in Japanese).

VAQUIER, V., S. UYEDA, M. YASUI, J. SCLATER, C. CORRY and T. WATANABE, 1966, Studies of the thermal state of the Earth. The 19th paper: Heat-flow measurements in the Northwestern Pacific, *Bull. Earthquake Res. Inst, Univ. Tokyo*, 44, 1519-1535.

VOLCANOLOGICAL SOCIETY OF JAPAN, 1971, List of the world active volcanoes, *Special Issue, Bull. Volcan. Eruptions*, IUGG.

YUASA, M., 1983, North-south geomorphological descrepancy observed in Izu-Ogasawara Island-arc, *Earth Monthly*, 5, 459-463, (in Japanese).

DELP 1987年度　小笠原海域航海報告

I：概説

DELP 背弧海盆研究班

1987年の秋に DELP 研究・調査の一環として本研究グループは小笠原海盆の地学的探査及び海底からの試料の採取を実行した．この海域は小笠原諸島と七島硫黄島火山列の間に挟まれた深い(3500-4200 m) 海盆を形成し，またこの海域の東側には太平洋全域でも最も年代の古い海洋底プレートが在り，この海域のプレートの下側に潜り込んでいる．また太平洋プレートによって東方から運ばれてきた海山列が小笠原（前弧）諸島に衝突しているためか，或はパレスベラ海盆と四国海盆の間の非同期的海洋底拡大作用の結果として，この海域全般には錯綜したテクトニクス的作用力が働いたと推定され，地史は第三紀以降だけでも複雑である．

調査は，エアガンによる多重式反射法地殻構造音波探査，ダイナマイト及びエアガンを音源とし，海底地震計を受波装置とする屈折法地震構造探査，地磁気異常分布探査，海底地殻熱流量探査，ドレッジおよびコアラー等の項目について行われた．これらの探査結果は，今日までに得られている他の探査結果等と融合あるいは比較検討の結果，この地域におけるテクトニクス的古環境に関する基礎的なデータを提供するはずであるが，探査結果の詳細な解析は，更に日時を要し本稿の作製時の現在においても，参加各研究機関において続けられており，ここに掲載された内容については，近い将来にも改訂される可能性があることをお断りしておきたい．

また研究・調査航海に際しては，日本サルベージ株式会社所属の若潮丸および東海大学所属の東海大学丸二世号の両船舶並びに関係諸氏にはひとかたならざるお世話になった．この紙面を借りて謝意を表したい．