東京大学地震研究所付属
海半球観測研究センター

自己点検報告書

２００６年2月

東京大学地震研究所
海半球観測研究センター

はじめに

海半球観測研究センターは東京大学地震研究所の付属施設として平成9年4月に10年の時限で設置された．したがって研究所は，時限の切れる平成19年3月をひかえて，全所的観点でこの間のセンターの活動を総括し，その後のあり方について検討する必要性を早くから自覚していた．

ところが平成16年4月におこなわれた東京大学の法人化の結果，センターを時限10年の地震研究所付属施設とするという法制上の根拠は失われ，センターは，東京大学がその独自の意志に従って設置する学内施設という性格を持つものとなった．とはいえ，設置から10年という時期は，センターの活動を振り返り，それが果たしてきた役割を明らかにし，今後の発展の方向を定めるための適切な機会であることには変わりはない．

そこで研究所では，平成17年10月27日の教授会において，センターの外部評価を行い，これまでの活動を総括するとともに，平成19年4月以降のセンターのあり方について，その活動の諸領域について造詣の深い国内外の専門家の方々の意見を伺うこととした．本報告書は，そのために海半球観測研究センターが用意した自己点検報告書である．

１．概要

1-1. センターの設立の経緯とその後の経過

地球のさまざまな活動は局所的に閉じたものではなく，地球内部と大気・海洋さらには地球外天体までもが密接に相互作用を及ぼしあっていることがしだいに明らかになってきた．全地球規模のマントル対流が，日本列島の地震や火山の活動を引き起こし，地球環境変動にも影響を与える．このような新しい地球認識の潮流に対応し，地球上に起こる自然現象を真に理解するためには，一地域・一分野にとらわれない，地球全体を見渡す観測研究が必須であることは，多くの研究者の意見の一致するところである．そして，地球全体を見回したとき，地球表面の70％を覆う海洋底は大陸地殻の複雑さにじゃまされずに地球内部を覗くための窓ととらえることができる．しかし，同時に海洋地域は陸域に比べるとあらゆる地球観測にとっての観測空白域になっており，特に最大の面積を占める太平洋の観測空白域の存在が新しい地球観の創造に最大の障害となっていることがわかる．この太平洋を含み海洋域が90％以上を占める半球（これを「海半球」Ocean Hemisphere と呼ぶ）に観測ネットワークの展開をはかるのは急務であり，また日本は太平洋広域観測の前線基地としてネットワークの拠点となるための絶好の場所にある．

このような観点のもとに，平成8年度から5か年計画で科学研究費創成的基礎研究（新プログラム）「海半球ネットワーク」プロジェクトが実施された．海半球観測研究センター（以下，センターという）は，海半球関連観測研究の中心拠点として，本学大学院理学系研究科および海洋研究所の協力を得て平成9年4月に設置された．センターの目的は，太平洋を中心とする海半球に地球規模の地球物理観測網を構築・維持し，そのデータを国際的に交換することにより，地震・火山・地磁気などさまざまな地学現象の根源であるマントルとコアの運動とその原動力を解明することにおかれた．

センターは，地震研究所の中で最も新しく，また唯一10年時限（法人化以前の法制による）のついた組織である．10年時限をつけた理由は，科研費による5年に加えさらに5年間「ポスト海半球」の研究を実施することによって得られる成果を背景に，組織改編を含む新たな研究の展開をはかることをあらかじめ想定したためである．時限を区切って集中的な研究プロジェクトを実施するというのも，本所にとってはじめての試みであったため，人員配置についても全所的なサポートを受け，予算定員を大きく上回る，8名の教官と1名の技術職員という体制で発足した．

センターには大きく分けて4つの役割が期待された．第一の役割は，観測の実施である．完成した海半球ネットワークの地球観測を長期的に実行するのに加えて，陸域や海域において機動的なアレー観測等を実施してきた．第二に，さまざまな地球観測をこれまでにない精度・感度で行うために，従来の装置を使用するだけでなく，独自の観測装置や周辺機器の開発を行う役割がある．特に「海半球」のネットワークには海底における長期観測は不可欠の要素であり，長期型海底地震計・電磁力計や長期型海底孔内地震計など，高い性能の装置の開発を行ってきた．第三の役割は，観測データの解析を行い，地球内部の構造やダイナミクスの研究を行うことである．研究成果の章で紹介するように，さまざまな観測データを総合的に用いることにより，地球活動の真の解明に取り組んできた．最後にデータセンターとしての役割をあげることができる．観測データが内外のできるだけ多くの研究者に利用されるべく円滑なデータ流通をはかるとともに，国際的なデータ交換の窓口としての役割も果たし

てきた．

科研費による海半球計画は，1 年の計画延長の申請が認められて平成 13 年度までの 6 年間実施された．その後，陸域の地震および電磁気観測ネットワークは海洋科学技術センター（現，海洋研究開発機構）へ移管し，観測網の維持を共同で実施する体制へと移行した．この体制においてセンターは，各観測点からのデータ伝送（テレメータ）の部分を主として分担し，その結果研究者にかかる観測網維持の負担が大幅に軽減された．その一方，平成 16ー20 年度科学研究費特定領域研究「地球深部スラブ」における海陸の機動観測の実施をはじめ，大気を含む振動現象や火山などにおける固体と流体の複合系で発生する現象の研究など，さまざまな研究を展開してきた．そして，これらの多くの研究が，センター内あるいは研究所内に閉じることなく，国内外の研究者との共同でなされていることは特筆すべきであろう．

2-2. 組織と運営

(1) センターの構成

平成１７年度のセンターの構成は以下のようになっている.

センター構成員：

教授：	歌田久司，川勝均（センター長），金澤敏彦（併任）
助教授：	塩原肇，山野誠
助手：	市原美恵，清水久芳，竹内希，馬場聖至，綿田辰吾
技術専門職員：	松嶋信代（情報処理室）
研究員：	志藤あずさ，HARCOUET Virginie，SHI Xue-Ming
研究支援推進員・技術補佐員：	横山景一
外来研究員：	市来雅啓（JAMSTEC）
大学院生：	浅利晴紀，濱元栄起，高橋優志，大木聖子，川上慶高，馬場祐太
客員教員：	NIU Fenling (Rice U., USA), D. S. RAMESH (NGRI, India), PALSHIN Nick A. (RAS, Russia), 深尾良夫（JAMSTEC），末次大輔（JAMSTEC）

Center member:

Professor:	UTADA Hisashi, KAWAKATSU Hitoshi (Director), KANAZAWA Toshihiko (joint appointment)
Associate Professor:	SHIOBARA Hajime, YAMANO Makoto
Research Associate:	ICHIHARA Mie, SHIMIZU Hisayoshi, TAKEUCHI Nozomu, BABA Kiyoshi, WATADA Shingo
Secretarial Staff:	MATSUSHIMA Nobuyo
Research Fellow:	SHITO Azusa, HARCOUET Virginie, SHI Xue-Ming,
Technical Support Staff:	YOKOYAMA Keiichi
Adjoint Researcher:	ICHIKI Masahiro
Graduate Student:	ASARI Seiki, HAMAMOTO Hideki, TAKAHASHI Yuji, OHKI Satoko, KAWAKAMI Yoshitaka, BABA Yuta
Visiting Professor:	Fenling NIU (Rice U., USA), D. S. RAMESH (NGRI , India), PALSHIN Nick A. (RAS, Russia), FUKAO Yoshio (JAMSTEC), SUETSUGU Daisuke (JAMSTEC)

Research group (faculty member):

Global Seismology:	H. Kawakatsu, S. Watada, N. Takeuchi
Global Geomagnetism:	H. Utada, H. Shimizu
Geothermics:	M. Yamano
Ocean Bottom Seismology:	H. Shiobara, T. Kanazawa
Ocean Bottom Geomagnetism:	H. Utada, K. Baba
Physics of Multi-phase Systems:	H. Kawakatsu, S. Watada, M. Ichihara
Data Center:	N. Takeuchi, H. Shimizu

センター発足時には教員は，教授 1，助教授 4，助手 3 の構成であったが，その後の新規採用等を経て現在の構成となっている．発足時の構成メンバーの内，深尾良夫（元）センター長は平成 16 年 3 月をもって海洋研究開発機構へ移動，森田裕一助教授・飯高隆（元）助手は所内の他のセンターに移動した．

(2) 運営

センターの運営は，特別な運営委員会などを置くことはなく進められている．研究所外部（学内・学外）との調整は，日本学術会議グローバル地球物理観測小委員会などを通して行われてきた．また地震研究所内の調整は教授会および所内各委員会での議論を通して行っている．

一方センター内では，不定期的に教員会議を開催し，予算・人事などの重要事項に関しての意見交換を行っている．また，研究上の意見交換は，週一回開催される「海半球セミナー」の場で行われる．

(3) 研究所本体との関係

本センターの教授・助教授・助手の教員は，本所の他の教員と同じ職務上の権利及び義務を有する．またセンターの人事・予算などは，本所の教授会の決定に従う．

センターの教員は，他の教員と同様に，所のさまざまな委員会に属し，地震研究所の運営に関わっている．以下に述べる予算案の策定も含め，研究所全体との一体的な管理・運営が行われていると考えることができる．

(4) 予算

他の部門・センターと同様，センター関係の年度予算は研究所予算委員会のもとで決定され，経理係のもとで管理される．平成 17 年度に即していえば，予算の示達をまって 6 月の研究所予算委員会および教授会において承認されている．実行上のセンター経費は全体で約 5000 万円となっており，このうちデータセンター関係の通信費，観測機材・ネットワークの維持費，センターの運営費をのぞく約 2700 万円が，センターとしての研究を遂行する目的で使われている（表 2.2.1）．今年度は新任助手の環境整備，海陸機動地震観測機器整備，熱流量観測および機器開発，微気圧アレー観測および機器開発などにあてられた．この他，科研費特定領域，および各教員の獲得した科研費等外部資金などをあわせると，実際の予算規模はこれをかなり上回る．

(5) 客員教員

センターには発足時，国外・国内それぞれ 1 名の客員教員（当時は教授）ポストが用意された．実際の運用にあたっては，所の共同利用の枠の中で，所の他の同様のポストとひとまとめにして扱われ，共同利用委員会で承認を受けることとなっている．その際，海半球センター長の強い推薦がある場合，国内・国外それぞれ一名については，その旨を考慮することとなっており，実質的にセンターの希望にそった客員教員の選考ができるようになっている．

選考にあたっては，センター内で希望を募り，センター長が調整をおこない推薦にあたる．招聘期間は，国内客員は 1 年通年，外国人客員は概ね 3〜4 か月となっている．客員教員には研究室が提供され，東京大学あるいは民間の宿泊施設を利用する際の便宜もはかられている．

この間，それぞれの研究課題に即してセンター教員との共同研究を行い，その成果の一端を所外にも広く公開されたセミナー等において報告することとなっている．

外国人客員教員

予定中のものも含め，平成 9 年度から 18 年度までの 10 年間に招聘した外国人客員教員は 22 名（うち 2 名は 2 回，のべ 24 名）となっている．所属機関の国別では，アメリカ 6 名，ロシア 5 名，カナダ 3 名，中国 3 名，台湾 1 名，フランス 1 名，ノルウェイ 1 名，インド 1 名，ベトナム 1 名（計 9 か国）である．これらの客員教員は，センターが推進する地球内部観測研究の分野の世界の第一線の研究者，または国際共同研究の担当者である．本客員制度は，センターおよび所の国際交流の推進に大いに貢献してきただけでなく（具体的な成果としては例えば Vinnik et al. (1998, 2001); Mielde et al., (2001); Kawakatsu and Bina (2001); Mielde et al. (2002a, 2002b); Utada et al., (2003); Ramesh et al. (2005); Kuvshinov et al. (2005) などがある），個々の客員教員を通してセンター・所の研究を国外に知らしめるよいきっかけともなっており，今後も継続されていくことが望ましい．しかしながら，運用にあたっては，客員教員の滞在期間が重なってもよい（年度内の総計期間が 1 年を超えない範囲で），年度を超えた招聘を行ってもよい，などの弾力的な運用が可能かを検討すべきであろう．日程調整がつかず招聘を断念せざるを得ない場合，また日程調整のために多くの時間を費やしてしまう場合などがあり，現行より使いやすい制度にすることは可能であろう．

国内客員教員

国内客員については，センターの推進する研究を日本国内で広めていくための手段，また共同研究の安定的推進のための手段として戦略的に運用され，センター活動に貢献してきた．今後も同様のポストが維持されることが望ましい．

表 2.2.1. 平成 17 年度センター実行予算（17 年 1 月 20 日見込み）

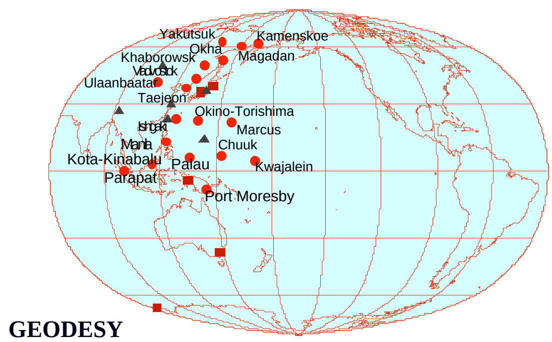
使途	物品費	国内旅費	外国旅費	その他	謝金	計
センター運営費	1,792,188	0	0	0	2,827,440	4,619,628
ネットワーク維持費	0	110,287	2,547,743	8,720,080	0	11,378,110
データセンター運営費	717,294	0	0	6,482,706	0	7,200,000
新任教員研究環境整備	1,750,000	0	0	0	0	1,750,000
陸上機動地震観測機器	12,789,525	33,480	0	0	0	12,823,005
海底機動地震観測機器	7,884,257	0	0	0	0	7,884,257
熱流量観測・機器開発	1,750,000	0	0	0	0	1,750,000
微気圧アレー観測・機器開発	2,516,290	310,710	0	0	0	2,827,000
合計	29,199,554	454,477	2,547,743	15,202,786	2,827,440	50,232,000

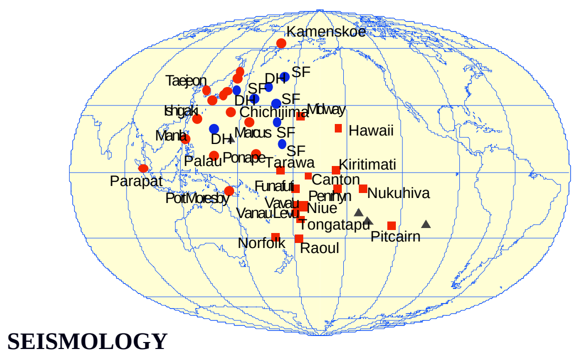
2. Research Activities

2-1. Execution and Management of Big Projects

2-1-1. Ocean Hemisphere Network Project (OHP)

The Ocean Hemisphere Network Project (OHP), supported by a Grant-in-Aid for Creative Scientific Research (New Program) from the Ministry of Education, Science, Sports and Culture (Monbusho), was carried out during 1996–2001 to obtain new observational findings that will provide a new view of the Earth's interior. For this purpose, a network of multidisciplinary geophysical observatories was constructed and long-term observations were carried out in the Ocean Hemisphere, especially in the western Pacific region, which has long been recognized as the largest spatial gap in terms of global coverage of geophysical data. The OHP began in 1996, involving the collaboration of more than 50 scientists from the University of Tokyo and other universities and national institutions. The total budget was approximately 1,700m yen for the 6 years of the project. The Ocean Hemisphere Research Center (OHRC) (involving both scientists and support staff) functioned as the core of the entire project both in terms of research activity and management. The project ended in 2001 with the completion of the OHP network (Fig. 2.1.1) of 14 onland broadband seismic observatories (most sited on Pacific Islands), three seafloor borehole seismic observatories, 10 onland geomagnetic observatories, one seafloor geomagnetic observatory, seven submarine cables used to measure geo-electric field variations, 19 GPS stations, five stations for superconducting gravimetry, and a data center (see also Sections 2-5 and 2-6). Analysis of data from this multidisciplinary geophysical observation network, as well as data from temporary observations and existing observatories, has led to the publication of significant scientific results. The major outcomes of the project are summarized below.





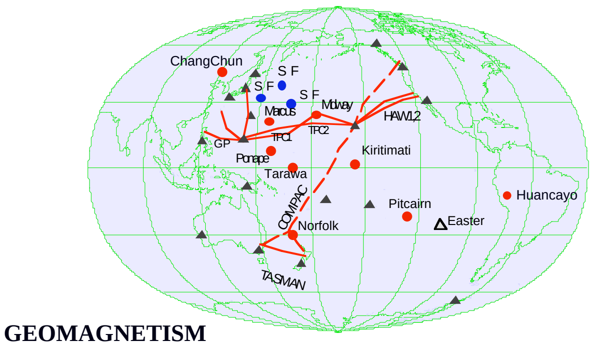


Fig. 2.1.1. Geodetic, Broadband Seismic and Geo-electromagnetic components of the Ocean Hemisphere Project network.

(1) Discovery of the Earth's background free oscillations

A surprising phenomenon was discovered, in that free oscillation of the solid Earth occurs continuously even in the absence of excitation by major earthquakes. The first discovery of this phenomenon was made from a time-series analysis of data from superconducting gravimetric stations of the OHP network (e.g., Suda et al., 1998). As shown in Section 2-4, scientists in the OHRC have consistently led this new area of study from its initial discovery to demonstrated proof of its global nature and subsequent development of the research field.

(2) Whole mantle seismic tomography

A new method of whole mantle tomography has been developed that is optimized to image a particular part of the mantle–the mantle beneath the western Pacific region where the OHP network was deployed in the present case–with the highest resolution. This method has been termed the 'non-uniform grid method', and has been used in a number of studies. This method provides a clear image of underlying high-velocity material in the transition zone that indicates stagnation of the slab material supplied from the western Pacific subduction zone (Fig. 2.1.2). The concept of a 'stagnant slab' was first proposed on the basis of these results. This concept is contradictory to the concept of slab penetration proposed by the MIT group, and therefore caused great controversy, related in part to the problem of whether mantle convection is single- or double-layered. Later improvements in the amount and quality of data (Obayashi et al., 2003), as well as inversion schemes and tomographic studies at much larger scales, have revealed the presence of stagnant slabs in transition zones within various circum-Pacific subduction zones (Fig. 2.1.3), thus demonstrating its global nature (Fukao et al., 2001). Thus, the OHP tomography group made a significant contribution to understanding the physics of mantle convection.

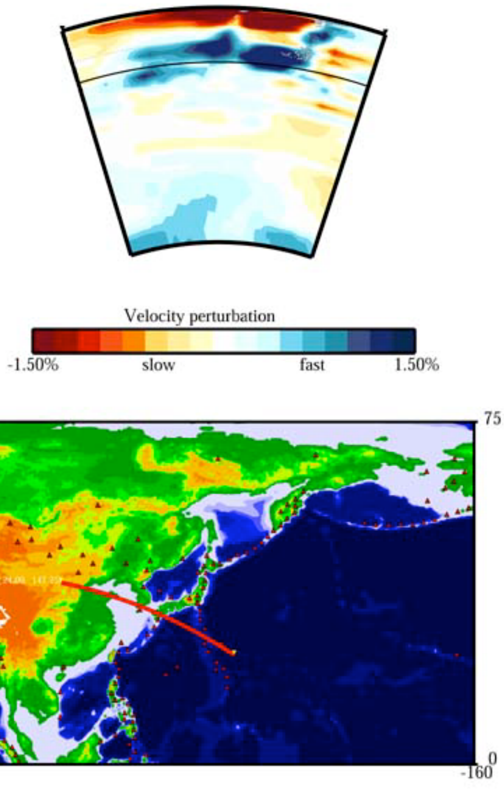


Fig. 2.1.2. Cross-section of P-wave velocity perturbation along the great circle shown by the red line on the map. A stagnant slab is imaged as a large high-velocity anomaly in the transition zone beneath southwest Japan and East China.

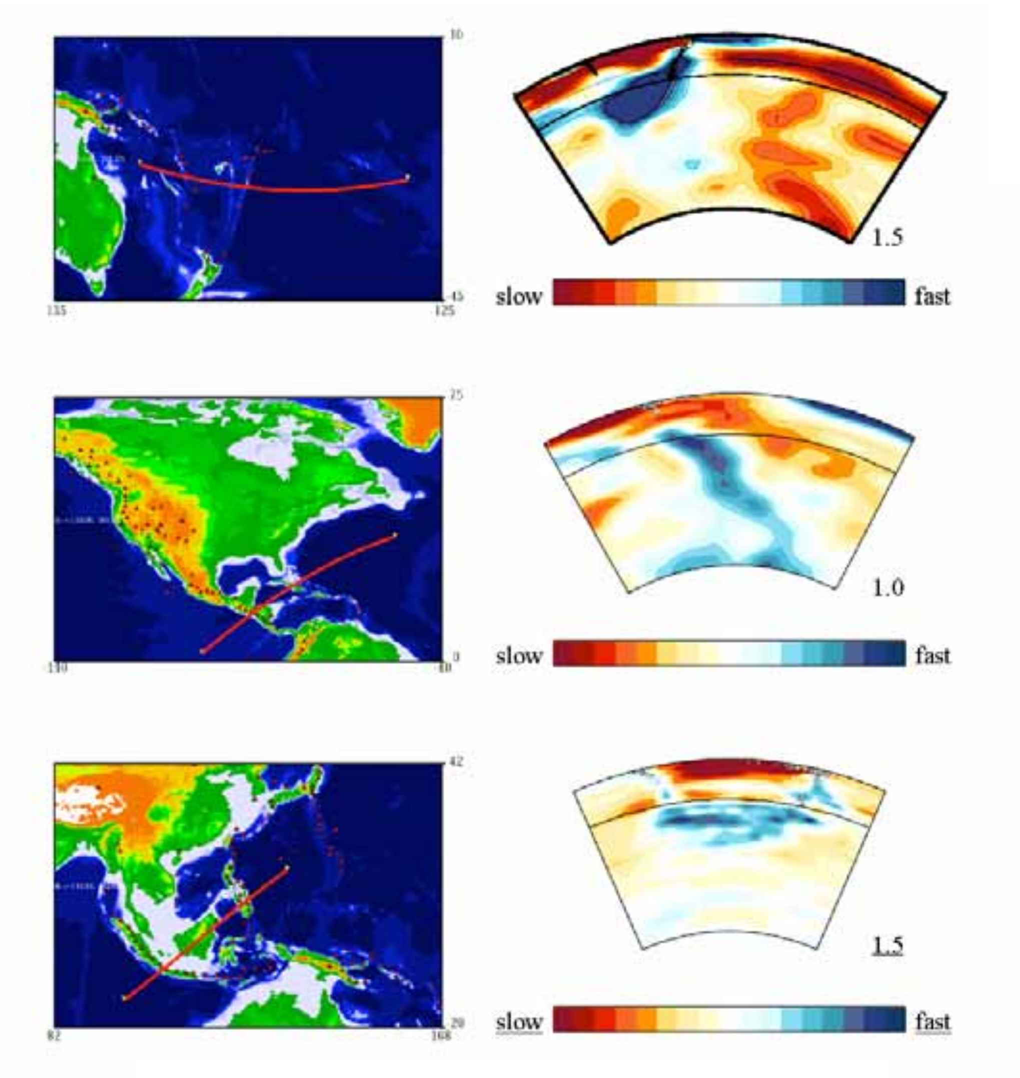


Fig. 2.1.3. Stagnant slab images from the southwest Pacific Ocean (upper), Central America (middle) and Southeast Asia (lower).

(3) Study of fine structures of the mantle transition zone

Seismic investigations were performed in the western Pacific region to reveal detailed structures of the mantle transition zone, which are considered to be one of the major factors controlling convection patterns in the mantle. Two important results were obtained from this project. The first is the discovery of new seismic discontinuities/reflectors in the uppermost part of the lower mantle at depths of 900–1200 km, immediately below the stagnant slab (Niu and Kawakatsu, 1997; Vinnik et al., 1998; Fig. 2.1.4). This newly discovered discontinuity/reflector is considered to be strongly related to an abrupt change in the tomographic image at approximately 1200 km depth. The second main result is the successful estimation of the density distribution in the transition zone beneath Japan (Kato and Kawakatsu, 2001). This was the first case in the world of an in situ estimate of density distribution, which is considered to be the most difficult challenge in seismology. This study clearly showed that it is possible to determine the density distribution within the transition zone, which is one of the sources of the driving force of mantle convection, by applying the method introduced in this study to data analysis from different regions.

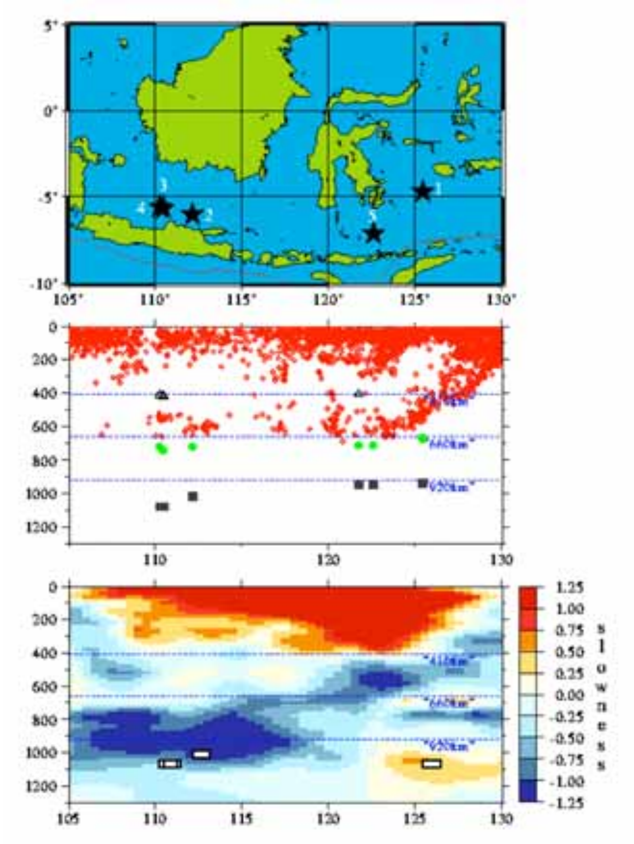


Fig. 2.1.4. Seismic discontinuities/reflectors beneath the Indonesia arc. Upper: map view. Middle: location of discontinuities/reflectors. Lower: tomographic image of the region (after Vinniki et al., 1998).

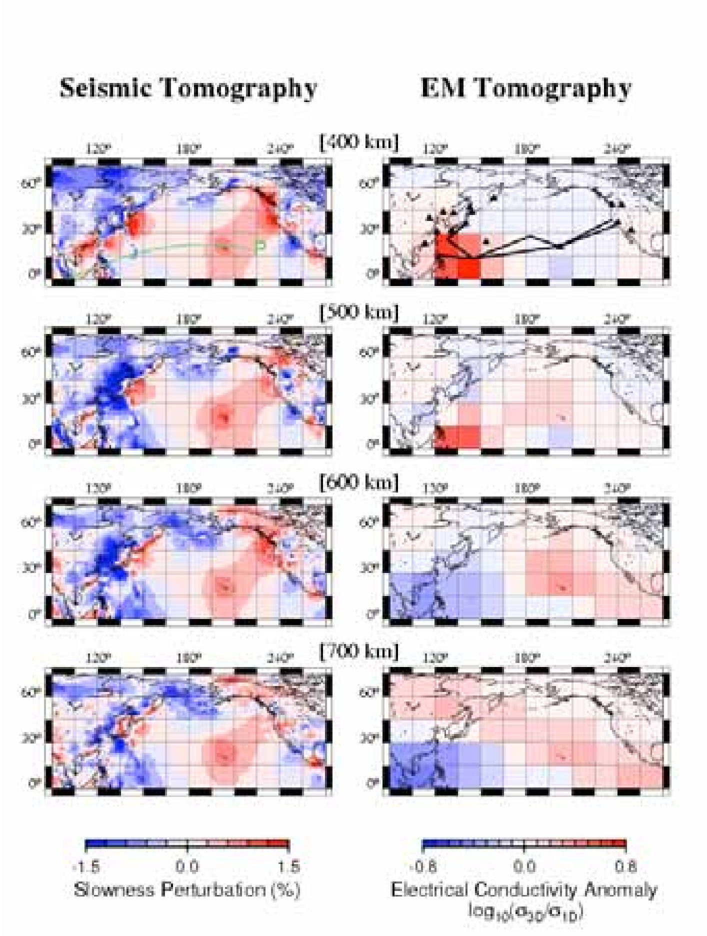


Fig. 2.1.5. Comparison of EM tomography (right) and P-wave tomography (left) of the north Pacific region at the depth range 300–800 km at 100 km intervals.

(4) Semi-global mantle electromagnetic tomography

An effective code was developed for forward and inverse problems of 3-D electromagnetic (EM) induction. Using the inversion code, EM response functions estimated from geomagnetic and geo-electric data derived from OHP geomagnetic stations, the OHP submarine cable network, and existing geomagnetic observatories, were inverted to a 3-D electrical conductivity distribution (Fig. 2.1.5). This distribution is defined as a perturbation of conductivity, from a semi-globally averaged 1-D reference (Utada et al., 2003), in the upper and mid mantle for the quarter of the globe that is centered by the North Pacific Basin (Fukao et al., 2004). A joint interpretation was attempted for the EM and P-wave tomography, assuming that both are ascribed to temperature anomalies. Results of this interpretation indicate that major anomalies, such as the conducting and low-velocity anomaly beneath Hawaii and the resistive and high-velocity anomaly in the lower part of the transition zone beneath the Philippine Sea, can be simply explained by temperature anomalies of 100–200 K. However, the conducting anomaly in the upper part of the transition zone beneath the Philippine Sea is not accompanied by a seismic velocity anomaly. This indicates that an additional effect is necessary to consistently account for these features.

2-1-2. Stagnant Slab Project (SSP)

As one of the post-OHP science programs, the Stagnant Slab Project (SSP) was proposed as a 5-year project and funded in 2004 by a Grant-in-Aid for Scientific Research in Priority Areas (MEXT) to carry out an intensive and multidisciplinary study on mantle dynamics with the key term of “stagnant slab.” The project is organized by eight subgroups (three in seismology, one in EM, two in high-pressure science, and two in computer simulation). The total budget of approximately 1,400m

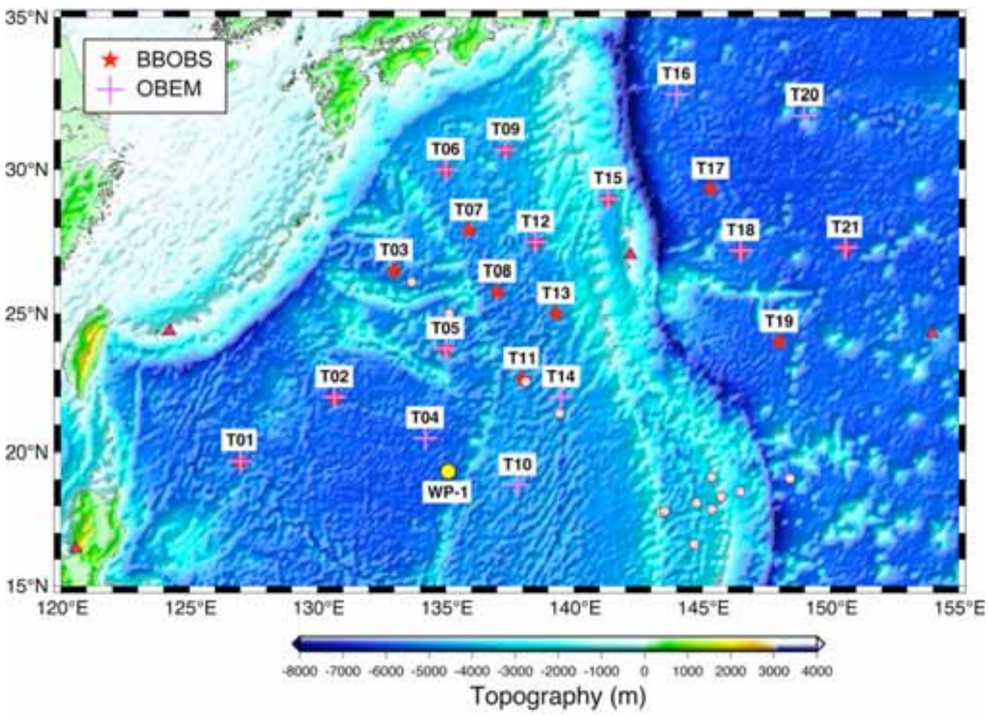


Fig. 2.1.6. Locations of BBOBS (red dot) and OBEM (pink cross) sites deployed as part of the Stagnant Slab Project.

yen will be supported for five years. More than 70 scientists are participating this project from more than 10 research institutions throughout Japan. Again, the OHRC plays an important role in both research activity and project management of the SSP. Various collaborations in this project are expected to lead to a better understanding of the mechanism of slab stagnation and subsequent descent of the slab into the lower mantle, as well as further reveal the effects that these processes have had on the history of plate motions and the entire Earth history.

Scientists in the OHRC are involved in two subgroups that carry out long-term seafloor seismic and EM observations to provide datasets for high-resolution seismic and EM tomographies, particularly for the region beneath the Philippine Sea where a vast amount of slab material is stagnant within the transition zone. In October 2005, the first SSP cruise was carried out by the R/V Kairei of JAMSTEC (Japan Agency for Marine Science and Technology), in which 16 broadband ocean bottom seismometers (BBOBSs) and 11 ocean-bottom electro-magnetometers (OBEMs) were installed (Fig. 2.1.6). These instruments will be recovered in 1-years time, when a second set of instruments will be deployed at mostly the same locations. By repeating such installations, a three-year observation using BBOBSs and OBEMs is planned to provide more reliable datasets to improve the resolution of seismic and EM images of the stagnant slab and surrounding area. These two research groups will thus contribute to the goal of the SSP by determining the distribution of physical parameters that control mantle dynamics.

2-2. Ocean and Land Observations

2-2-1. Seafloor Seismic Observation

Since initial experimental attempts at the Japan Sea in 1989 and the Atlantic Ocean in 1992, there have been few broadband seismic observations on the seafloor until the OHP began practical observations in 1999 in the northwest Pacific Ocean and the Philippine Sea. From the beginning of the OHRC in 1997, we have been developing broadband and long-term seismic observation systems for the seafloor that are able to interpolate the global seismic network, which has only sparse coverage over large oceanic areas; this is a principal goal of the OHP. Two types of systems have been developed: the Seafloor Borehole Seismic Observatory (SBSO) as stable stations within the global seismic network, and BBOBS for long-term but mobile array observations. These systems are based on our long experience of ocean bottom seismometer development, and were developed in cooperation with members of the Earthquake Observation Center (ERI) and JAMSTEC. Figure 2.2.1 shows the locations of these stations during the OHP period; this represents the first step for ocean bottom broadband seismology. After several successful experimental observations by the BBOBS, we began practical array observations in 2003, as described later in the text.

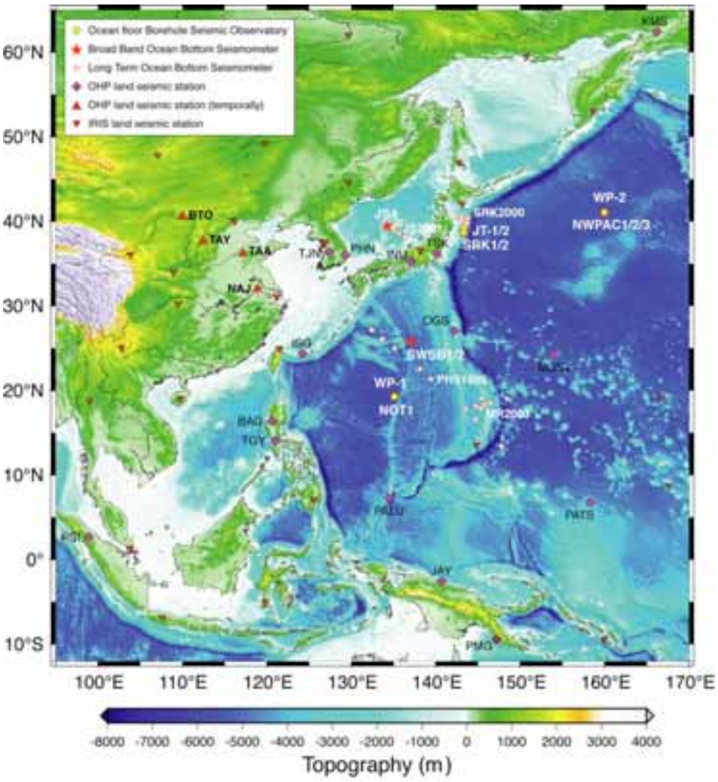


Fig. 2.2.1. Location map of seafloor seismic stations employed during the OHP.

The four SBSOs were constructed as part of the ODP program to drill the boreholes and install the heavy main unit on the seafloor, with the final setup and maintenance performed using the ROV "KAIKO" (JAMSTEC). The JT-1 and JT-2 stations were built in 1999, mainly to monitor seismic and geodetic signals on the continental shelf in areas with different background seismic activities. As part of the global seismic network, WP-1 and WP-2 have been working since 2001 and 2000, respectively. These stations have two sets of broadband sensor units cemented in place near the bottom of the borehole, and data is stored at the re-entry cone (Fig. 2.2.3). At the WP-2 station, we have successfully obtained data over a period in excess of 400 days, which has yet to be bettered by any seafloor borehole seismic station. The data quality is also good compared to previous seafloor borehole seismic stations, as shown in Fig. 2.2.4; noise level is low and stable over time, comparable to a quiet inland station (Araki et al., 2004; Shinohara et al., 2006).

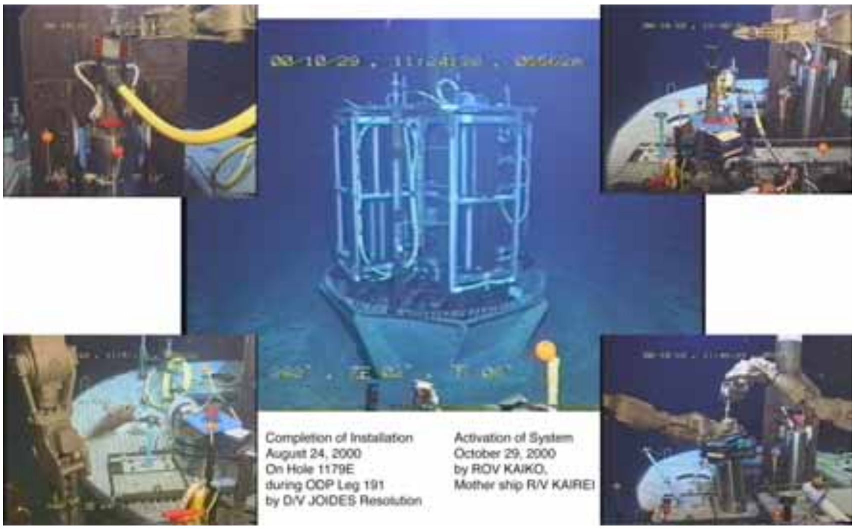


Fig. 2.2.2. Photographs of the WP-2 during final setup.

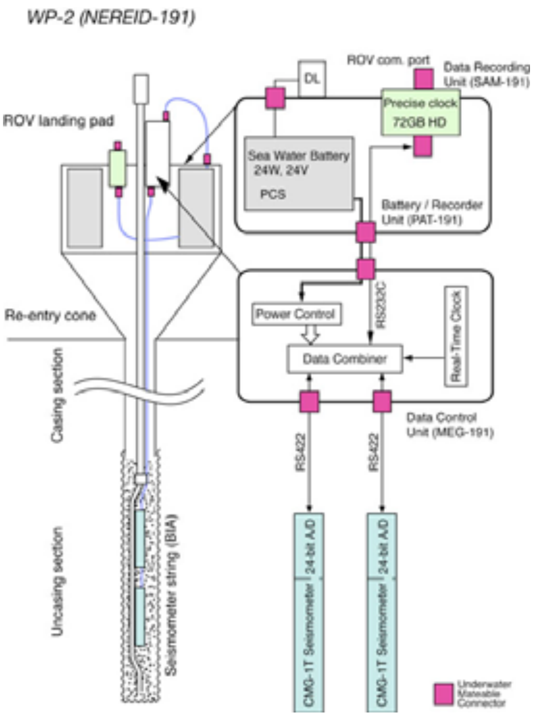


Fig. 2.2.3. System diagram of the SBSO.

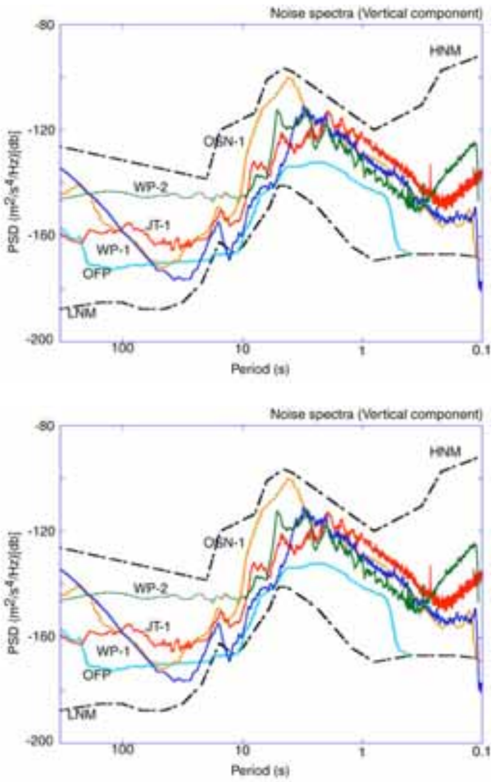


Fig. 2.2.4. Noise levels of the seafloor borehole stations.

A trade-off of the SBSO's high performance is the difficulty in increasing the number of stations. To address this problem, the mobile BBOBS and long-term OBS (LTOBS) have been developed to compensate the global network and perform array observations to achieve better spatial resolution; these are operated by free-falling deployment and self-popup recovery. The BBOBS (Fig. 2.2.5) has a titanium sphere (D=65 cm) that contains a broadband sensor with a leveling unit, a data recorder with a high-precision clock, an acoustic transponder unit, and lithium cells for power supply. The LTOBS is similar to the BBOBS, although the sensor does not provide long period coverage and it has a smaller sphere (D=50 cm). After the first experiment with the LTOBS at the East Pacific in 1997, the first BBOBS (NWPAC1) was deployed at the same position as the WP-2 in 1999, with successful recovery in 2000. From the 1-year data by the BBOBS, the noise model is indicated with that of the KIP land station (Fig. 2.2.6), which shows good performance in the vertical component. The reason for the relatively high noise level in the horizontal components is probably tilt variation of the BBOBS sphere due to tidal bottom current. To reduce this noise level, we are now developing a new generation BBOBS system with a separate sensor package that is stuck in the sediment but is still mobile.

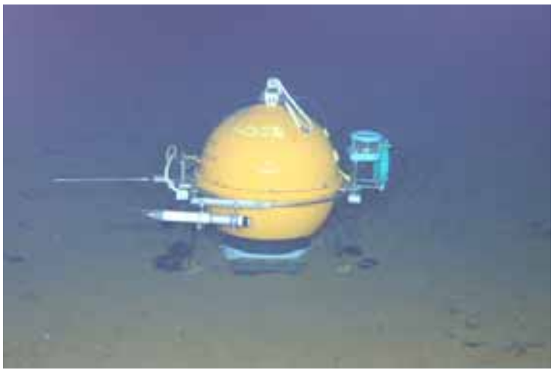


Fig. 2.2.5. Photographs of the BBOBS on the ship deck (left) and upon the seafloor

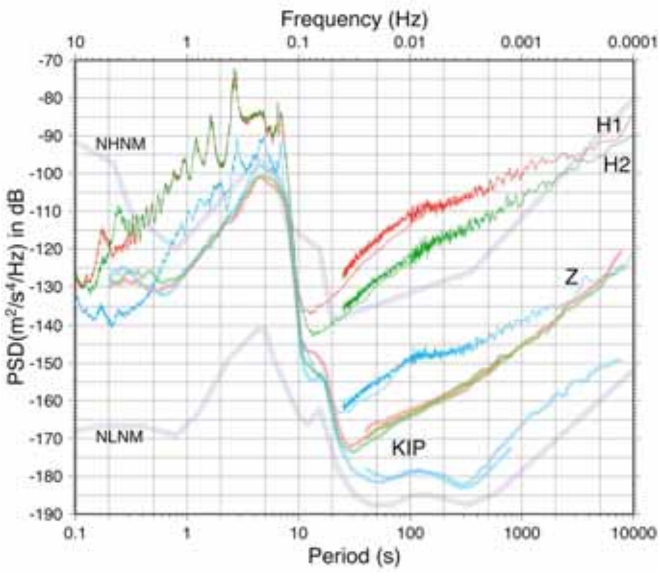


Fig. 2.2.6. BBOBS noise model of NWPAC1 and 2

As examples of research into the Earth interior using seafloor seismic observations, we describe two results from the Mariana LTOBS array observation (MR2001) and a combined study of several observations in the Philippine Sea using a receiver function analysis. The former experiment involved using 10 LTOBS to conduct a 1-year passive observation around the active deep seismic zone to investigate the subduction system. The array detected more than 3000 local events, while the PDE list recorded only about 60. By using a simultaneous inversion method with the event data set, we found that the hypocenter distribution shows a clear deep double seismic zone down to 200 km depth, and determined the velocity structure of the upper mantle (Fig. 2.2.7). The latter study used data from various observations by LTOBS (PHS1999), BBOBS (NOT1), and SBSO (WP-1) in the Philippine Sea (Suetsugu et al., 2005). Fig. 2.2.8 shows the main result: shallow (410 km) and deep (660 km) discontinuities were determined at the site WP-1. Our results also indicate that this variation in depth within the Philippine Sea may be related to the morphology of the stagnant Pacific Slab.

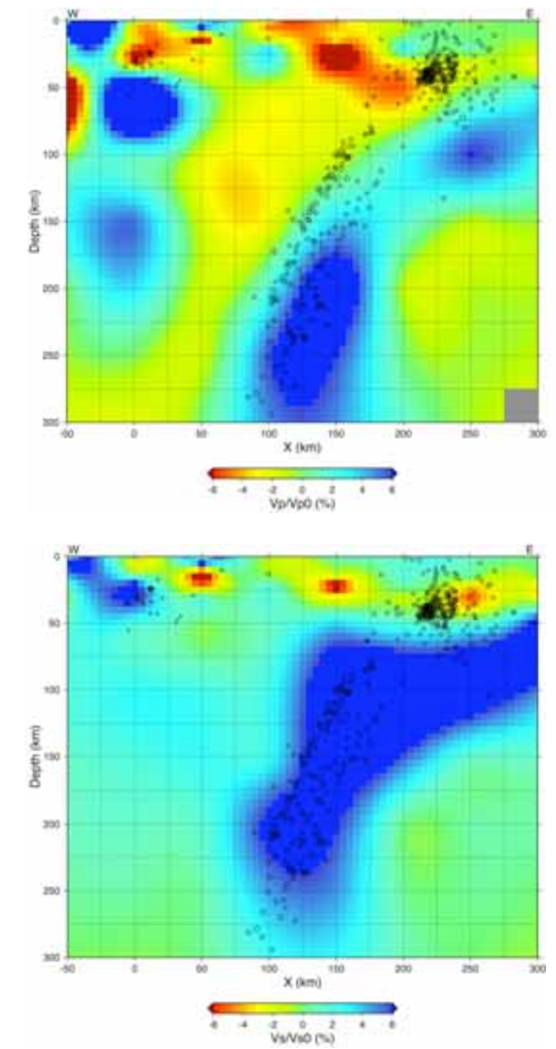


Fig. 2.2.7. Hypocenters and velocity structure from the data of MR2001 observation (Vp and Vs, relative to IASP91).

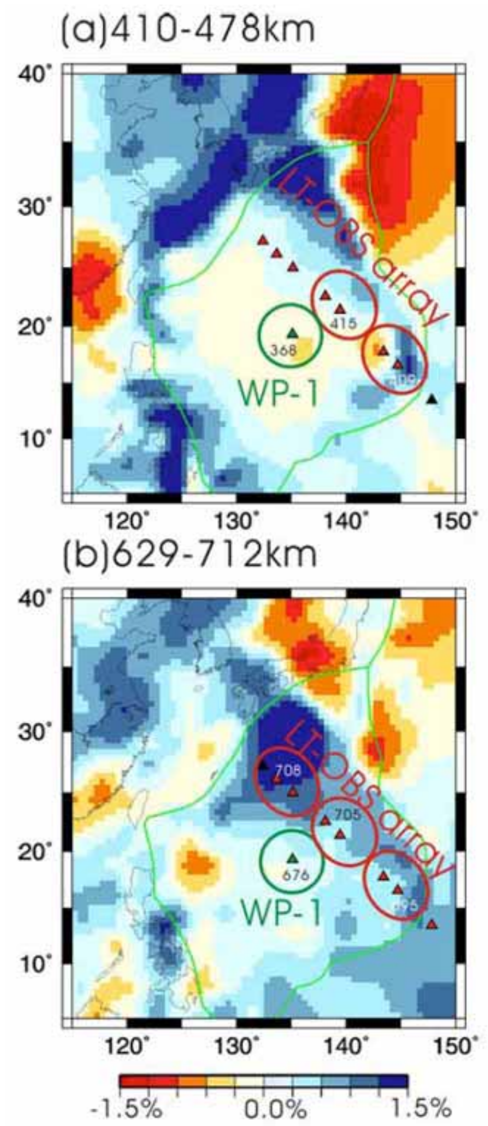


Fig. 2.2.8. Depth of upper mantle discontinuities derived from a global tomography result.

From 2003 to 2005, we made cooperative land and ocean-floor observations in French Polynesia with IFREE (Institute For Research on Earth Evolution) of JAMSTEC and French scientists (the PLUME Project; Suetsugu et al., 2005). Finally, data from nine of the ten deployed BBOBS were obtained for the entire deployment period with a remarkably low micro-seismic noise level. Preliminary analysis using a receiver function method shows a normal upper mantle discontinuity depth, except for the area around the S2 station that is probably related to the Society Hotspot. Another large-scale observation in the Philippine Sea and northwest Pacific, the Stagnant Slab Project, began in 2005 and is to continue until 2008, using 12 or 16 BBOBS.

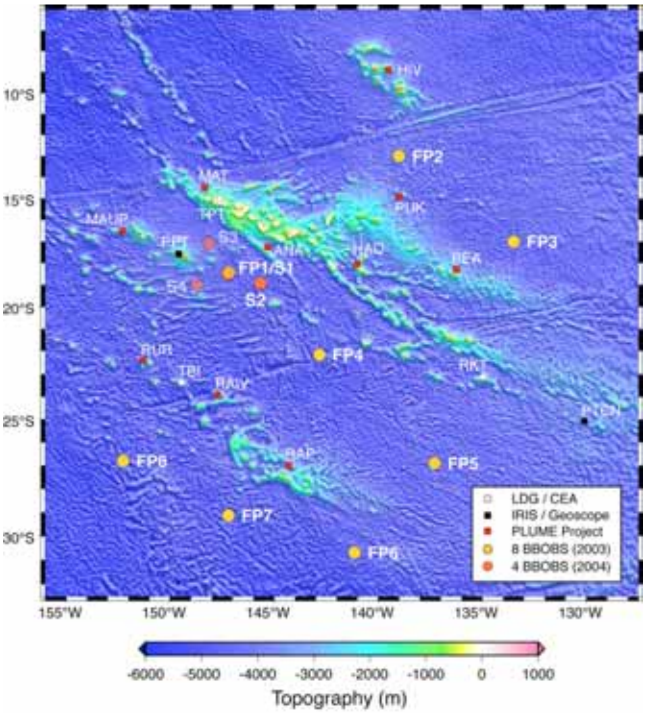


Fig. 2.2.9. Location map of the PLUME Project in French Polynesia.

2-2-2. Land Seismic Observation Network

(1) Permanent network

Japanese researchers began to deploy an international seismic network in the Western Pacific region as a part of the POSEIDON (Pacific Oriented SEISmic Digital Observation Network) Project in 1987. The POSEIDON Project is not a large funded project but a non-funded collaboration between individual researchers who are interested in global seismic observations. The observation systems, data formats, and policy for data distribution were not unified, and the POSEIDON network did not essentially function as a single network.

After the establishment of the OHRC, we established a unified and modern seismic network (OHP Network) by improving the POSEIDON stations in collaboration with researchers from another institutes. We unified the observation systems to STS-1 and a data logger developed by the Nagoya University. We have also been deploying real-time data transmission systems since 2002. We established the Ocean Hemisphere Project Data Management Center (OHPDMC) to distribute the observational data to the public (see Section 2-6).

(2) Portable networks

We are also deploying portable networks to supplement coverage by permanent stations. We developed a data logger that is suitable for portable observations in foreign countries where a sufficient quality of electrical power and communication lines cannot be guaranteed. Our system uses a compact HDD for data storage, which enables long-term and stable observation. Using this system, we deployed portable networks in China (four stations deployed between 1998 and 2003) and Vietnam (six stations deployed since 2001; Fig. 2.2.10). This system was also adopted in other projects (JISNET and SPANET).

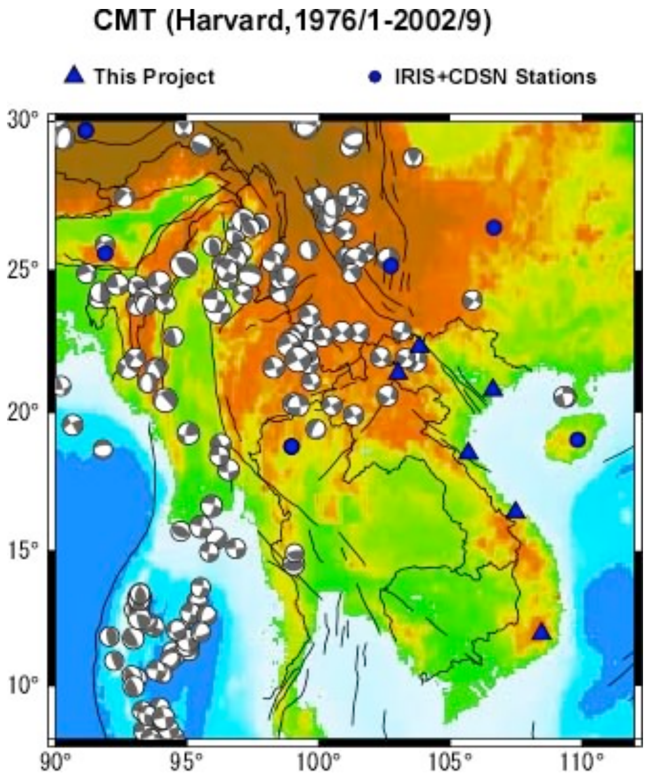


Fig. 2.2.10. Location map of portable seismic stations in Vietnam (blue triangles). Permanent IRIS and CDSN stations are indicated by blue circles.

(3) Education

We provided training for our counterparts in maintaining our stations and analyzing observational data. We invited two trainees from Indonesia in 1999 and one from Vietnam in 2002. We also invited 14 trainees from the China Seismological Bureau to train in skills for data analysis.

2-2-3. Seafloor Electromagnetic Observations

Electromagnetic observations on the seafloor surrounding Japan have been carried out by the OHP, the Stagnant Slab Project, and related collaborative studies with other institutions (Fig. 2.2.11). These experiments contribute to the study of semi-global scale mantle dynamics in the region by conjunct analysis as well as the study of various tectonic settings.

(1) Philippine Sea experiment

Six ocean bottom electromagnetometers (OBEMs) were deployed on the seafloor of the West Philippine Basin, the Parece-Vela Basin, and the Mariana Trough in November 1999 and subsequently recovered in July 2000. From these data we estimated the 1-D electrical conductivity structure of the

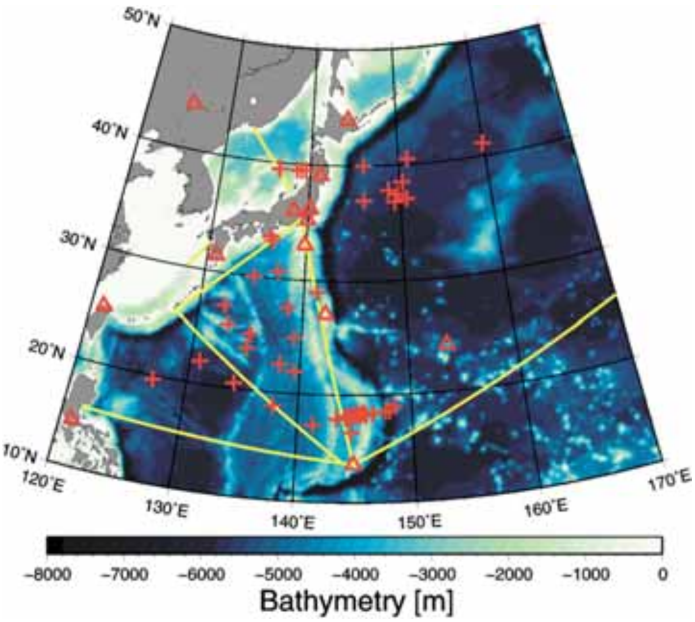


Fig. 2.2.11. Seafloor electromagnetic observation sites deployed as part of the OHP network, Stagnant Slab Project, and related projects (crosses), superimposed on a bathymetry map of the Japan region. Triangles represent onland geomagnetic stations, while lines indicate submarine cables used for electric field measurements.

upper mantle at each site (Seama et al., submitted to Phys. Earth Planet. Inter.). The experiment demonstrated the excellent potential of this method to investigate the geothermal structure and water and melt content of the upper mantle.

(2) Sea-Floor Electro-Magnetic Station (SFEMS)

The SFEMS was developed to achieve continuous seafloor observation of absolute geomagnetic total force as accurately as land-based observatories, including the vector geomagnetic field and horizontal electric field (Toh et al., 1998). The SFEMS has been in operation at 41°07’03”N, 159°55’43”E in the northwest Pacific Ocean since August 2001. The data collected to date demonstrate that the seafloor observatory can contribute to improving the spatial resolution of the existing geomagnetic observatory network in the middle of the northwest Pacific, where long-term geomagnetic data are lacking (Toh et al., 2004).

(3) Mariana experiment

Seafloor magnetotelluric (MT) experiments in the central Mariana region have been used to investigate mantle dynamics associated with plate subduction, arc volcanism, and back-arc spreading. A pilot survey was conducted using 10 OBEMs during 2001–2002. The obtained data were inverted, and the resultant electrical conductivity model suggests that the melt generation process within a back-arc spreading axis is similar to that of normal oceanic spreading. Further experiments at 40 sites using 47 instruments began in December 2005 under international collaboration.

(4) Japan Sea experiment

The aim of this experiment was to image the back-arc mantle beneath the eastern Japan Sea. Six OBEMs were utilized during 2002–2003. Useful data were acquired from four OBEMs and analyzed together with onland data. The obtained conductivity model demonstrates a high conductivity zone that indicates a relationship with the root of the “hot fingers”, which is as cluster-like distribution of volcanoes and low velocity anomalies in northeast Japan.

(5) Earth's electric Field Observation System (EFOS)

EFOS was developed with the aim of measuring the electric field of the Earth on the seafloor using a long (10–100 km) cable. It is expected that measurements using EFOS will enable us to detect the electric field that originated from toroidal magnetic mode penetrated from the outer core. A prototype with a 10 km cable (EFOS-10) was installed using JAMSTEC's deep-tow and ROV technology upon the Daito Ridge, West Philippine Basin. Comparison of the data collected over a 1-year period with data from the submarine cable TPC2 and data collected from an OBEM demonstrate the successful operation of the EFOS.

(6) Northwest Pacific experiment

A 1-year seafloor MT survey using OBEMs was conducted during 2003 with several cruises in the Northwest Pacific Ocean to investigate the electrical conductivity of the upper mantle and transition zone. In this region, a remarkable low-velocity anomaly was imaged from global seismic tomography, and very young (within 1 Ma) intra-plate volcanism was detected (Hirano et al., 2001; Obayashi et al., 2006). One of the goals of this experiment is to elucidate the relationship between these phenomena through the seafloor MT survey. Data have been collected at seven sites to date, and analysis is ongoing.

(7) Stagnant slab experiment

As part of Stagnant Slab Project, a long-term semi-global scale seafloor MT experiment using OBEMs has been planned to image the mantle transition zone beneath the Philippine Sea, where the subducting Pacific plate appears to have stagnated above the lower mantle. Eleven OBEMs were deployed in October 2005 at sites covering the northern West Philippine Basin, the Shikoku Basin, and the northern Parece-Vela Basin, at ~500 km spacings. This survey is just the first phase of the experiment. The 1-year measurement will be iterated three times to acquire sufficient data to image the transition zone.

2-2-4. Onland Electromagnetic Observations

We have been conducting geo-electromagnetic observations in northeast China to reveal the electrical conductivity structure of the upper mantle, especially around the depth of the mantle transition zone. A highly seismic velocity anomaly documented in the area beneath northeast China–East China Sea is interpreted as a stagnant slab. Understanding the electrical conductivity structure of the back-arc region is essential to consider the physical state of the stagnant slab and the origin of back-arc volcanism in northeast China.

Observation of the magnetic field began in 1998 at Changchun, China, and regional-scale electric field observations using retired telephone cables of lengths 20–40 km have been performed since that time in collaboration with the Institute of Geology, China Earthquake Administration. Long-period geomagnetic depth sounding (GDS) and magnetotelluric (MT) responses have been obtained. The responses were then inverted to 1-D electrical conductivity structures that are representative of the structure beneath the magnetic station and cables. The resultant electric conductivity profiles in the Jilin area, China, are shown in Fig. 2.2.12, together with those for Tucson, USA (red dashed line), Carty Lake, Canada (blue dotted line), and Honolulu, USA (green chain-shaped line). It is evident that the mantle transition zone beneath northeast China is significantly more conductive than those of the other areas. Similar patterns of electrical conductivity were observed in the western and central parts of the Liaoning area.

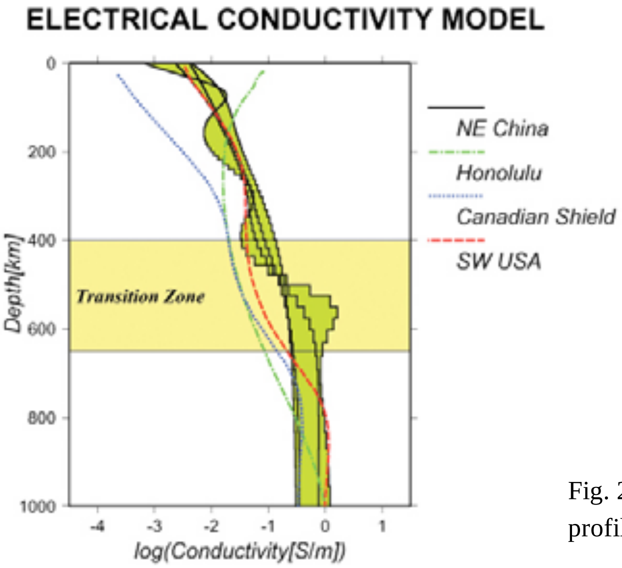


Fig. 2.2.12. Comparison of conductivity profiles. (from Ichiki et al. 2001).

We calculated profiles of temperature and water content in the upper mantle above the stagnant slab of the Pacific back-arc from the obtained electrical conductivity and seismic P-wave velocity (*V*p) structures. Geothermal profiles were determined from the conductivity and seismic structures assuming a dry hartzburgite or dry pyrolite composition. For the deeper part of the upper mantle (depth > 250 km), it is not possible to obtain a geotherm that satisfies both conductivity and seismic structures if dry hartzburgite or pyrolite is assumed. This discrepancy can be explained by allowing for a small amount of water (500–1000 ppm H/Si) in the mantle. In shallower parts of the upper mantle (depth < 250 km), the electrical and seismic geotherms are consistent with each other at 1500–1700 °C for dry hartzburgite, whereas they are inconsistent by more than 100 °C for dry pyrolite. Alternatively, a wet pyrolite composition applied to the deeper part of the upper mantle also satisfies the electrical conductivity and seismic *V*p structures in the shallower part. The proposed models that are consistent with both electrical conductivity and *V*p are shown in Fig. 2.2.13.

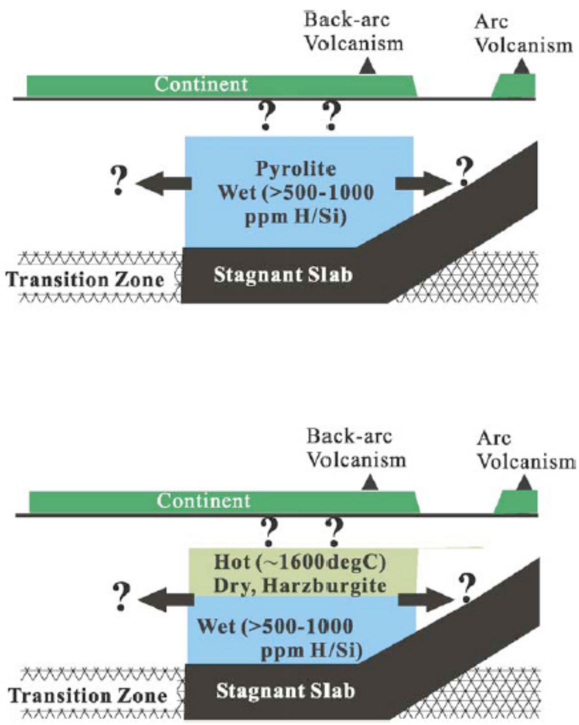


Fig. 2.2.13. Models that are consistent with both the seismic and conductivity anomalies beneath northeast China (from Ichiki et al., in press in Phys. Earth Planet. Inter.).

2-2-5. Heat Flow and Temperature Observations

(1) Thermal structure of the Nankai subduction zone, Southwest Japan

We have been conducting heat flow measurements in the Nankai Trough area to constrain the boundary condition of a thermal model of the Southwest Japan subduction zone. Concentrated measurements taken off eastern Shikoku (near Muroto) from 1999 to 2001 reveal that heat flow on the floor of the Nankai Trough is extraordinarily high, almost twice as high as the value expected considering the age of the subducting Philippine Sea plate (Fig. 2.2.14; Yamano et al., 2003). In contrast, data recently acquired off the eastern Ki-i Peninsula (near Kumano) show that heat flow on the trough floor in this area is normal. These results indicate that the thermal structure of the subducting plate varies significantly along the margin. We are now collecting data from the trough floor between the Muroto and Kumano areas to delineate the extent of the high heat flow anomaly.

Upon the accretionary prism, landward of the trough floor, heat flow profiles across the Muroto and Kumano margins are similar except for in the vicinity of the deformation front (Fig. 2.2.14). Heat flow decreases landward and reaches about 50 mW/m2 at around 40 km from the deformation front. These heat flow profiles provide constraints on the thermal structure of the subduction zone and the amount of frictional heating along the plate interface. Comparison of observational data with the heat flow profiles calculated using subduction thermal models indicates that frictional heating (i.e. effective friction coefficient) is very low in the Nankai subduction zone, consistent with results reported for Cascadia and other subduction zones.

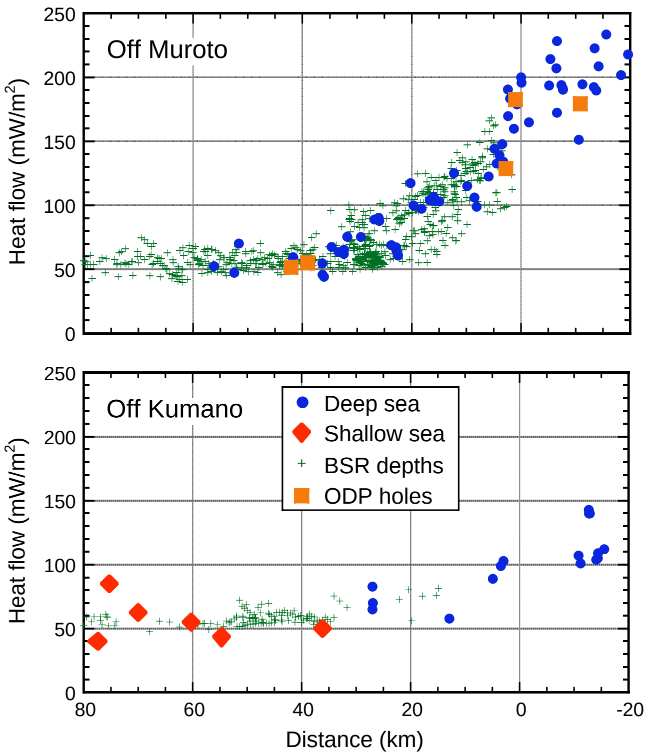


Fig. 2.2.14. Heat flow data from the Muroto and Kumano margins of the Nankai subduction zone plotted against distance from the deformation front.

(2) Heat flow measurements in shallow seas

It is difficult to obtain reliable heat flow measurements in shallow seas where the bottom water temperature is unstable. Long-term monitoring of temperatures in surface sediments may be a practical solution to this problem, and we have developed pop-up type temperature monitoring instruments for this purpose (Fig. 2.2.15). The instrument can measure the sediment temperature profile to a depth of 2 m over a period of about one year. We monitored temperature profiles in shallow sea areas of the Nankai subduction zone and obtained temperature records for over 200 days at seven stations. Analysis of the temperature data show that bottom water temperature variations (BTV) propagated through sediments solely by thermal diffusion. We were then able to remove the influence of BTV from the temperature records and determine the temperature gradient and heat flow at all stations (Hamamoto et al., 2005). The obtained heat flow values generally agree with those estimated from depths of methane hydrate BSRs in the vicinities of the stations. These results demonstrate that long-term temperature monitoring is a useful method for heat flow determination in shallow seas.

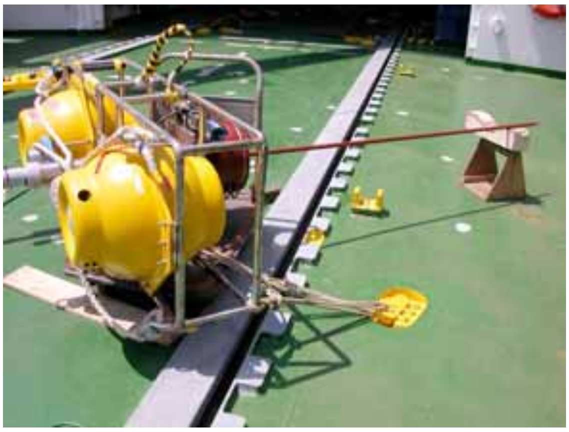


Fig. 2.2.15. Photograph of a pop-up type temperature monitoring instrument.

We also conducted temperature monitoring for about one year at three stations around cold-seep biological communities in the Nankai Trough area, using instruments deployed and recovered by submersibles. We estimated the vertical pore-fluid flow rate and heat flux by analyzing the obtained temperature records.

(3) Long-term temperature monitoring in boreholes

We have monitored the temperature profile in a borehole drilled into the Nojima fault, an active fault in southwest Japan, since 1997, using the distributed optical fiber temperature sensing technique. The temperature profile has been very stable until the start of a water injection experiment, and we did not detect any thermal effect of the 1995 Hyogo-ken Nanbu Earthquake (Yamano and Goto, 2001). During water injection experiments conducted in 2000, 2003, and 2005, temperature drops associated with the injected water were observed only above about 540 m. This clearly shows that the water leaked out of the hole at this depth (Yamano and Goto, 2005). Changes in the temperature profile were also observed when groundwater was flowing out of the borehole. The shape of the measured temperature profile indicates that the discharging water entered into the hole at the same depth (540 m).

(4) Compilation of heat flow data

We have been compiling heat flow data from the northwest Pacific area, including the Japanese Islands. The most recent version of the compilation covers an area from 0 to 60°N and 120 to 160°E, and contains heat flow data from 3195 stations. This data set was published with a list of references in 2004 as part of a CD-ROM (Yamano, 2004).

2-3. Structure and Dynamics of the Earth's Interior

2-3-1. Electromagnetic Structure and Core Dynamics

We studied the electrical conductivity structure of the upper mantle and uppermost part of the lower mantle beneath the Pacific region using magnetic field observatory data and newly obtained electromagnetic field data from the OHP (see Section 2-5). Our findings indicate the importance of the effect of land-sea conductivity contrast in obtaining proper structures (Fujii and Utada, 2000). This implies that the electromagnetic induction problem is inherently a 3-D one related to the effect of seawater, even if a 1-D mantle is assumed. We developed computer codes that model global and semi-global electromagnetic induction in a 3-D medium based on an integral equation method; these models are utilized to obtain PREM-like 1-D reference conductivity structure beneath the Pacific (Utada et al., 2003) and for the first successful 3-D inversion of semi-global electrical conductivity structure in the mantle (Koyama, 2002; Fig. 2.3.1).

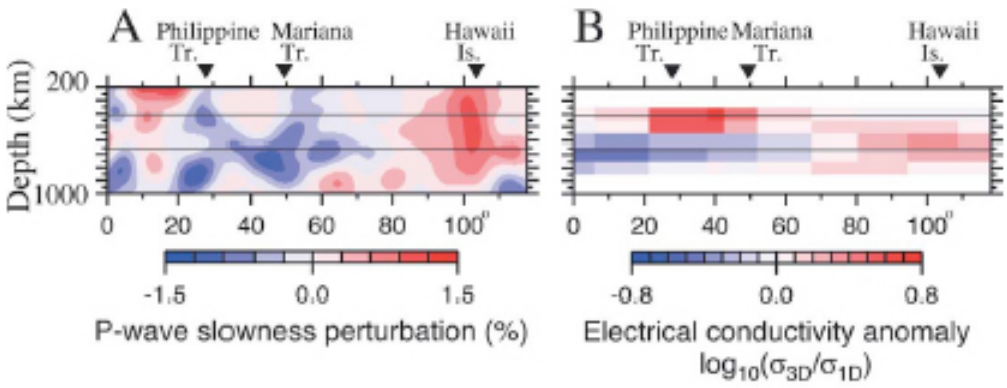


Fig. 2.3.1. Cross-section of the 3-D structure of electrical conductivity in the mantle beneath the Hawaii–Philippines region (right, from Fukao et al., 2004).

It is well known that the toroidal magnetic field must exist in the Earth's core in order for it to be a dynamo, although the component is confined in the core. Although the field cannot be detected by magnetic field observations at the surface of Earth, its signature is present in the geo-electric field and can possibly be detected by electric field observations using cables at the scale of thousands of kilometers. We began geo-electric field observations in the northwest Pacific with the aim of detecting the signature of the toroidal field (see Section 2-5). Long-term (decade-scale) variations in electric potential obtained to date indicate that decade-scale variation in the toroidal magnetic field at the core mantle boundary is 1–10 times that of the poloidal field variation, with reasonable electrical conductivity of the mantle (Shimizu et al., 1998). We confirmed that the amplitude is consistent with the electrodynamics of the geodynamo (Shimizu and Utada, 2004).

We are studying the small-scale magnetohydrodynamics within a rotating system as a step towards obtaining better parameterization of subgrid scale phenomena, especially the mean-field electromotive force, and establishing more realistic geodynamo models as a joint project with David E. Loper (Florida State University, USA) and Arnaud Chulliat (Institut de Physique du Globe de Paris, France). Structures of the flow and magnetic field driven by a buoyant blob are classified based on the strength of the rotation of the system and the magnetic field (Shimizu and Loper, 1997); detailed structures are obtained for the case of rapid rotation that is appropriate for the Earth's core (Loper et al., 2003;

Chulliat et al., 2004; Fig. 2.3.2). Although the integral of the electromotive force to the flow and field over entire space is zero, it has a significant non-zero value when integrated over the cross-section of the Taylor column, and it is significantly anisotropic (Shimizu and Loper, 2000; Chulliat et al., 2003, 2004).

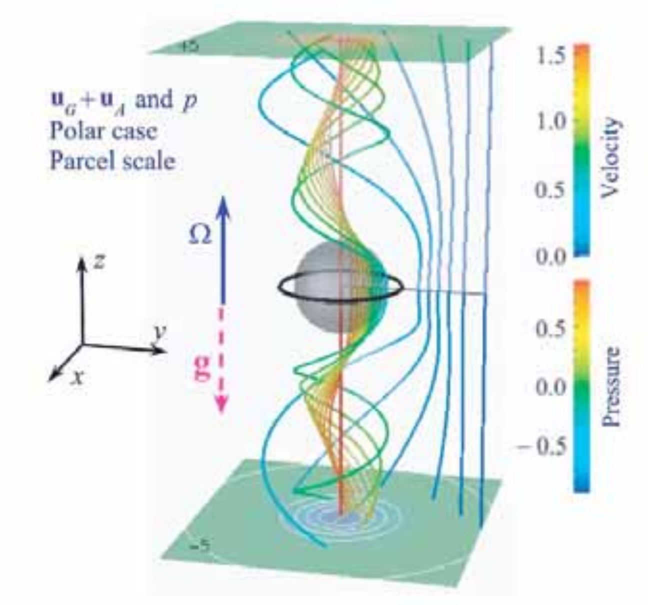


Fig. 2.3.2. An example of the structure of flow driven by a buoyant blob in a rotating magnetohydrodynamic system (from Loper et al., 2003).

The problem of the state of the inner core boundary (ICB), whether a mushy layer or a slurry layer, is revisited as a new joint research project with J.-L. LeMouël and J.-P. Poirier (Institut de Physique du Globe de Paris, France). Stability analysis of the solid-liquid interface indicates that the condition that leads to a slurry layer does exist, but it cannot be attained within the Earth's core; it is most probable that a mushy layer exists at the ICB.

Determining core surface flow by inverting geomagnetic secular variation with a frozen flux assumption has unavoidable physical non-uniqueness. We studied the use of length of the day (l.o.d.) data to overcome the non-uniqueness by assuming topographic (Asari et al., 2006) or electromagnetic core–mantle coupling. Cylindrical torque, which should be balanced in decade-scale core dynamics, is additionally considered both as a constraint to reduce the non-uniqueness and to obtain dynamically appropriate core surface flow (Asari, 2006). We found that only topographic core–mantle coupling is compatible with decadal cylindrical core dynamics.

2-3-2. Seismic Tomography

The highlight of tomographic studies within the OHP is the introduction of a unified story for the fate of subducting slabs (Fukao et al., 2001; Fig. 2.1.2–3). After Fukao et al. (1992) suggested the existence of stagnant slabs, various tomographic studies attempted to reveal further detailed slab structures. Compiling those results, we found that every major subduction zone in the world can be explained as a snapshot of the following subduction process: subducting slabs tend to be deflected within the Bullen transition zone (400–1000 km depth), but can sink into the lower mantle via an instability. To confirm the plausibility of this idea, we are now conducting a nation-wide project to reveal the nature and role of stagnant slabs.

Tomographic studies conducted within the OHP have also been characterized by efforts to develop unique techniques. We developed an efficient method to compute accurate synthetic seismograms for 3-D heterogeneous Earth models (Takeuchi et al., 2000), an appropriate weighting method to correct heterogeneous data sampling (Takeuchi and Kobayashi, 2004), and accurate methods for travel-time measurements to correct systematic bias in conventional methods (Fukao et al., 2002; Oki et al., 2004). These unique techniques have revealed important features of the Earth structure, including (i) boundary layers at 670 km depth indicated by the predominance of lateral heterogeneities with longer horizontal scale lengths in this region, and (ii) low R (=dlnVs/dlnVp) values in subducting slabs obtained by highly accurate S–P time measurements (Fig. 2.3.3).

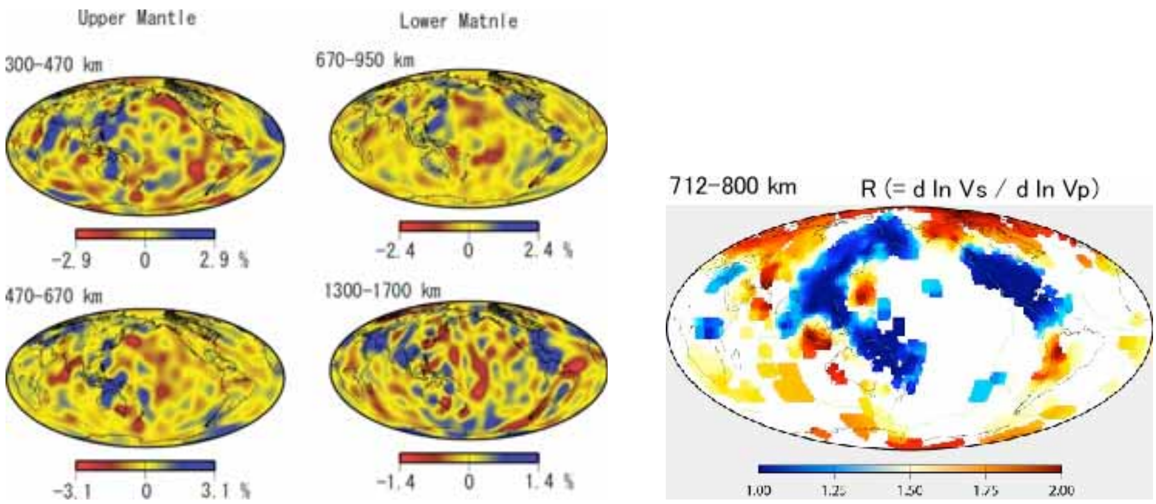


Fig. 2.3.3. (left; presented at the 2005 AGU fall meeting) S-wave velocity models obtained via the full waveform inversion of Takeuchi & Kobayashi (2004). Note the longer horizontal scale lengths of heterogeneities in the vicinity of 670 km depth, especially in upwelling regions. (right; presented by Oki, 2006, Ph.D. thesis) R (= dlnVs/dlnVp) model obtained from the accurate S–P time measurements of Oki et al. (2004). Note the smaller R-values in the subducting regions, which indicate that R-values are lower in high-Q media.

2-3-3. Array Seismological Studies of the Earth's Deep Interior

Although seismic tomography is a powerful tool to unravel hidden structures within the Earth's deep interior, its resolution remains limited. To supplement existing information on the Earth's deep interior, we used the array seismological technique, which is sensitive to small-scale (~10 km) heterogeneities. We have particularly focused on utilizing dense and high-quality Japanese network data (J-array, F-net, Hi-net) in an attempt to detect structures that were not detected in previous studies. Our earlier studies indicated the existence of discontinuities/reflectors in the mid-mantle (Kawakatsu and Niu, 1994; Kawakatsu and Niu, 1997; Vinnik et al., 1998, 2001; Fig. 2.1.4) and multiple discontinuities at the bottom of the mantle transition zone (Niu and Kawakatsu, 1996); other researchers have investigated both of these features in subsequent studies. We also succeeded in estimating the local density contrast at discontinuities in the mantle transition zone, which is a difficult parameter to estimate seismologically (Kato and Kawakatsu, 2001).

(1) Reflection seismology of the upper mantle

Recent studies utilize the large amount of high-quality Hi-net data. For example, to delineate the effect of the presence of a cold "deep mantle slab" on the mantle transition zone discontinuities, we conducted a receiver function analysis to finely map the seismic discontinuities beneath the Japanese Islands (Kawakatsu and Watada, 2005; Fig. 2.3.4). The obtained image shows remarkably clear continuous features corresponding to the 410 km and 660 km transition zone discontinuities; in addition, the top surface of the subducting Pacific plate is traceable to at least 300 km depth. While these general features are expected for a penetrating subduction, the observed 500-km-wide depression of the 660 km discontinuity beneath southwest Japan appears to be consistent with neither a simple penetrating slab nor a flat stagnating slab near the boundary. A model that involves a more complicated morphology of the stagnating slab structure may be required.

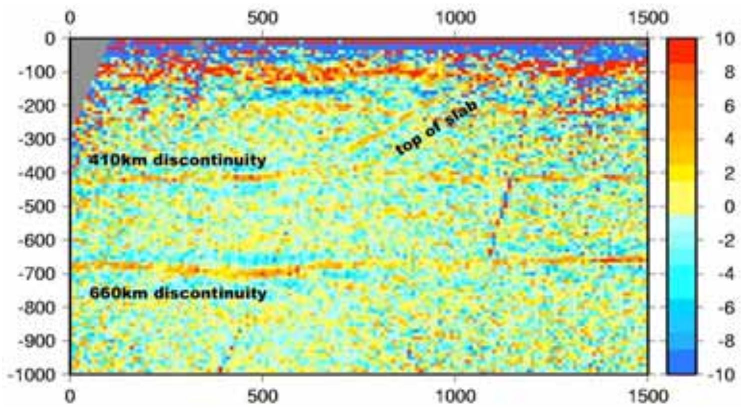


Fig. 2.3.4. Cross-section of P–S conversion energy beneath southwest Japan.

(2) Reflection seismology of the inner core

We have also made an unusual entire array observation of the near-vertical PKiKP phase, which is known to be very difficult to observe (Kawakatsu 2006, in press). Array analyses of this rare data set show a sharp (<~1 km) inner core boundary. Utilizing the PKiKP as a reference phase, a reflection seismological study of the inner core was possible for the first time. This study identified a possible discontinuity beneath the ICB.

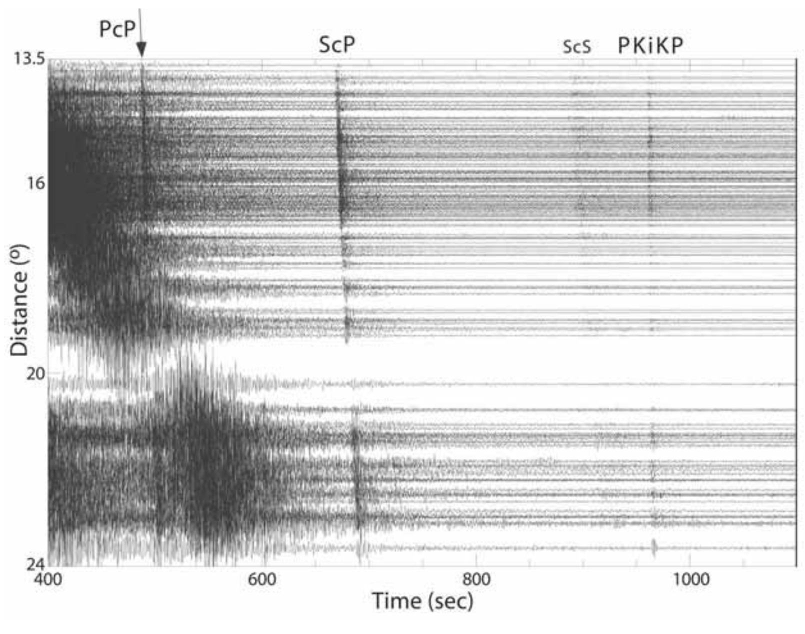


Fig. 2.3.5. Hi-net observation of PKiKP.

2-4. Solid-fluid Complex Systems in Earth Science ("Blue Earth Seismology")

2-4-1. Continuous Free Oscillations of the Earth

The discovery of incessant excitation of the free oscillations of the Earth started from the analysis of 3-year superconducting gravimeter data recorded at Syowa, Antarctica, as part of the OHP (Nawa et al., 1998). Numerous subsequent papers (e.g., Suda et al., 1998; Kobayashi and Nishida, 1998) confirmed that incessant oscillation is a global-scale phenomenon by analyzing continuous recordings of global seismic networks. The power spectrum of the continuous free oscillation shows clear seasonal changes, with the power being larger in the Northern Hemisphere winter and smaller in summer; this trend is common to all quiet seismic stations. Another prominent feature of the power spectrum of the oscillation is the excess amplitude of specific spheroidal normal modes, which are known to couple to long-wavelength acoustic modes trapped in the atmosphere. This resonant oscillation between the solid Earth and the atmosphere is termed Earth's hum (Nishida et al., 2000).

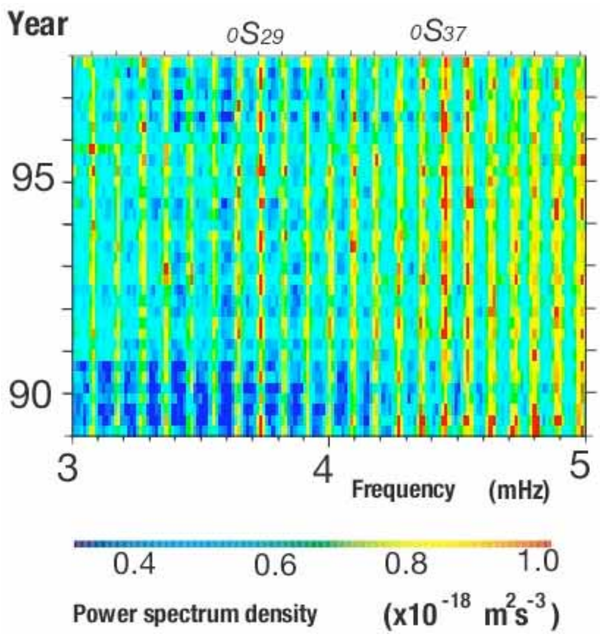


Fig. 2.4.1. Ground motion spectrum for seismically quiet days. Days are represented in the ordinate and frequencies in the abscissa. The vertical yellow lines indicate the incessant free oscillations of the Earth.

These observations led the idea that the main source of the continuous oscillations is atmospheric turbulence within thermal convective motion in the troposphere, as powered by solar influx via heating of the ground beneath the turbulent atmosphere. Modeling of the frequency-dependence of the observed power spectrum was conducted by assuming the ground surface is randomly and homogeneously buffeted in space and time by the atmospheric turbulence (Fukao et al., 2002). Parametric fitting in the modeling was successful only in the limited frequency band below 10 mHz and by assuming a characteristic scale length of the atmospheric turbulent motion. A 2-year local barograph array observation was conducted to measure the characteristic scale length of the atmospheric turbulence (Nishida et al., 2005). The barographic array observation demonstrated that the largest source of the atmospheric turbulence is wintertime wind, while measurement of the characteristic scale length was inconclusive in determining if atmospheric turbulence is the primary cause of the continuous free oscillations of the Earth.

Another powerful source of the continuous free oscillations of the Earth is within the ocean. Watada and Masters (2001) analyzed continuous ocean bottom pressure records from the deep sea and identified three characteristic features that support the oceanic excitation hypothesis: (i) the pressure power spectrum at the ocean bottom in the frequency range of 1-10 mHz is larger than the atmospheric power by one or two orders of magnitude, (ii) the frequency dependence of the power spectrum at the ocean bottom resembles that of the observed power spectrum of the continuous free oscillations, including the sharp drop in power beyond 10 mHz, and (iii) the spectrum power reaches a maximum during winter. The source regions of the continuous free oscillations can be directly determined from the analysis of the global broadband seismic array. The results show that seasonal and geographic changes of the excitation sources from the Pacific during November to February to high latitudes of the Southern Hemisphere from June to September, consistent to the oceanic excitation hypothesis.

2-4-2. Seismology in the Atmosphere

There are thee kinds of waves in the atmosphere in the frequency band above sub-milihertz: acoustic waves, Lamb waves, and gravity waves. These atmospheric waves are excited by various sources and mechanisms such as volcanic eruptions and earthquakes, and are observed as atmospheric pressure changes and ionospheric perturbations at distance sites. In research into active volcanoes, a simple pulse-like acoustic signal of a volcanic explosion directly indicates that the explosion process was simple, while a complex seismogram during a volcanic explosion reflects the propagation effect of seismic waves through the strong heterogeneous body. The harmonic excitation of seismic surface waves following the eruption of Mt. Pinatubo in 1991 at two specific frequencies is an example of resonant oscillations of atmospheric acoustic waves and the spheroidal normal mode of the Earth.

Watada et al. (2006) demonstrated from microbarometers deployed along the Japanese Islands that atmospheric pressure fluctuated during the passage of the Rayleigh waves following the 2003 M8.3 Tokachi-Oki Earthquake. By examining co-located broadband seismograms and barograms, the authors revealed that the pressure change is caused by ground motion beneath the microbarometers, and thereby constructed a transfer function between the vertical ground motion and pressure change up to a period of about 50 seconds. The observed transfer function is in good agreement with the theoretical transfer function.

Observation and analysis of these atmospheric waves, together with ground motion and ionospheric density perturbation records, will help to quantify the excitation sources and reveal previously poorly known behaviors of the Earth.

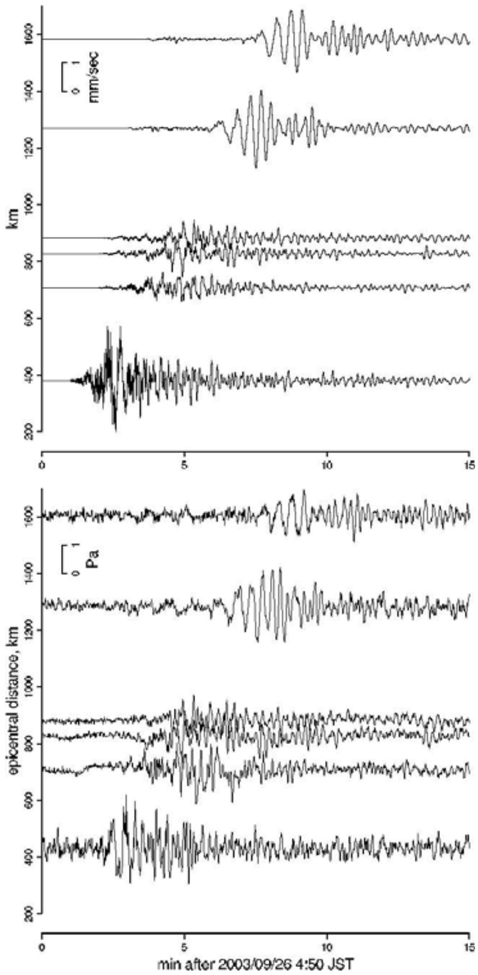


Fig. 2.4.2. Record sections of original velocity seismograms of the vertical component (upper) and filtered microbarograms (lower). Atmospheric pressure change travels at the same speed as seismic Rayleigh waves: approximately 3.2 km/sec.

2-4-3. Broadband Seismometry at Active Volcanoes

We have been deploying broadband seismometers, together with other geophysical instruments, at active volcanoes in Japan as part of cooperative research projects with Kyoto University, Tokyo Institute of Technology, Tohoku University, Kyushu University, and Hokkaido University. Of the research sites, the deployment at Aso Volcano is notable as it is recognized as one of the best examples in the field of volcano seismology in demonstrating the significance of broadband seismometry at active volcanoes.

Our observations using broadband sensors reveal the existence of unusually long-period (15 s) tremors (Fig. 2.4.3) that are continually emitted from the volcano regardless of surface activity and have several common spectral peaks that align with almost equal spacing (15, 7.5, 5, 4 s) (e.g., Kawakatsu et al., 2000). From the amplitude variation of these tremors, we detected the presence of a crack-like conduit whose strike and width are almost the same as those of the chain of craters illustrated in Fig. 2.4.4; this indicates that the chain of craters is the surface expression of a buried crack-like conduit (Yamamoto et al., 1999). Broadband records for phreatic eruptions (Fig. 2.4.5) show that this crack-like conduit also acts as a pressure buffer leading up to eruptions, and thus monitoring of the conduit may be the key to forecasting future activity at Aso Volcano.

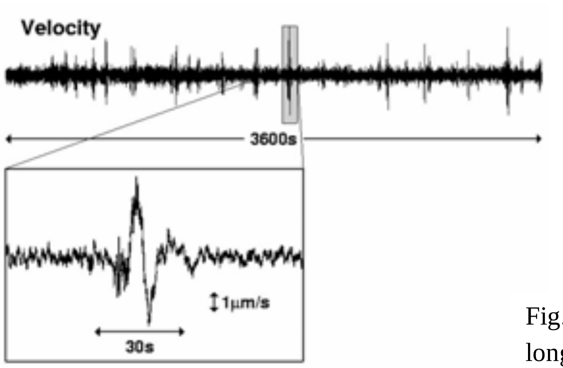


Fig. 2.4.3. Broadband records of long-period tremor(s) at Aso Volcano.

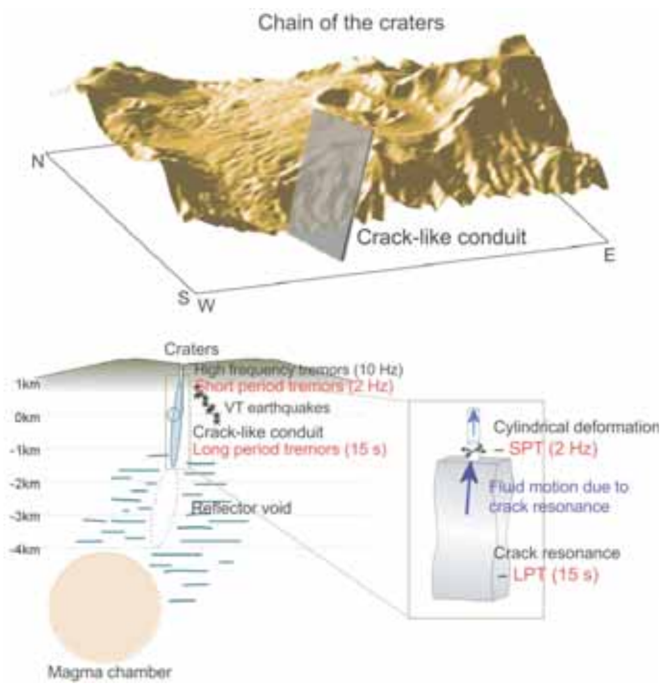


Fig. 2.4.4. Sketch of the crack-like conduit model.

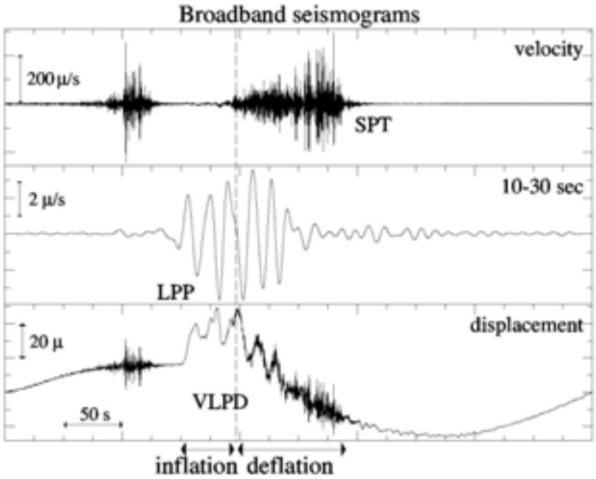


Fig. 2.4.5. Broadband waveforms of a phreatic eruption observed at Aso Volcano.

The existence of the crack-like conduit is also supported by other studies such as the reflection study, and the crack-like conduit is considered as a subsurface path that connects surface craters with a postulated magma chamber at a depth of around 5 km. We also studied the nature of other short-period seismic signals with periods of about 0.5 s and 0.4–0.1 s, using modern digital data obtained from dense array observations. Fig. 2.4.4 schematically summarizes the system beneath Aso Volcano as revealed by seismological analyses (Yamamoto, 2005). Such a line of volcanic conduit systems connecting the magma chamber and the surface has not been detected at any other active volcano in the world. Considering that the various volcanic signals are manifestations of dynamic interactions between volcanic fluids and the volcanic edifice in the conduit system, Aso Volcano appears to be one of the best sites to study the dynamic behavior of the volcanic fluid system beneath active volcanoes. We are currently constructing a real-time monitoring system of the activity of the crack-like conduit and fluid migration beneath Aso Volcano to understand how this system operates when magma rises to the surface in the leadup to an eruption.

2-4-4. Field and Laboratory Experiments to Study Oscillation of Multi-phase Systems Beneath Volcanoes

Volcanoes are good test sites at which to observe the geophysical phenomena of multi-phase systems. In this project we are studying the dynamics of magma transport and oscillation, taking account of coupling with surrounding rocks and the coexistence of solid, liquid, and gas phases within the magma.

(1) Propagation and attenuation of acoustic waves within bubble-bearing magma

Seismic signals passing from or through a volcano commonly indicate existence of a body or areas with slow sound speed and/or large attenuation, which are interpreted as bubble-bearing magma. Although it is well known in engineering systems that bubbles significantly decrease the speed and increase the attenuation of acoustic waves within the liquid, volcanic systems are more complicated and variable. We have proposed a mathematical model to evaluate the speed and attenuation of acoustic waves in bubbly magma that takes into account the large variation in viscosity and pressure within magma, as well as the diffusion of heat and volatiles, and time-dependent mechanical properties (Ichihara and Kameda, 2004). The mathematical model has been confirmed by laboratory experiments in terms of the effect of viscosity and viscoelasticity (Ichihara et al., 2004).

(2) Magma fragmentation and the generation of air-waves

Magma fragmentation occurs during explosive eruptions. Such fragmentation transmits pressure waves and magma fragments (pumices and ash) to the air and can cause natural disasters. We are conducting experimental studies of this process that focus on the mechanical properties of magma that control the conditions and behavior of magma, and the generation of pressure waves in the air by magma fragmentation at the ground surface. We measured and analyzed pressure waves in the air transmitted by underwater explosions and detected the influence of the disintegration of the water surface (Ichihara et al., 2005, proceedings).

(3) Bubble oscillation in magma and geothermal water

The oscillation of a single bubble is a fundamental process within more complicated systems that contain many bubbles. We are investigating the roles of a bubble or bubbles in the onset of volcanic eruptions and earthquakes (Ichihara and Brodsky, 2006).

2-5. Long-term Observation Network in the Ocean Hemisphere

(1) Seafloor borehole seismic observatory

During the life of the OHP, four seafloor borehole seismic observation sites were installed (e.g., Araki et al., 2004): JT-1 and JT-2 offshore from the Sanriku district, northeast Japan, installed in August 1999; WP-2 installed in the Northwest Pacific Basin in August 2000; and WP-1 installed in the West Philippine Basin in April 2001. The systems at JT-1 and JT-2 include strain and tilt sensors as well as seismometers. Observations by high-quality broadband seismogram at WP-2 continued for more than 400 days, which is a record duration for such observations. This long-term record enabled us to estimate how noise levels change throughout a year and prove the high efficiency of borehole seismometry at this site, which can detect seismic signals from earthquakes of greater than M3.5 that occur at any location in the world.

(2) Onland broadband seismic observatories

There were many difficulties in maintaining broadband seismic stations installed by Japanese group prior to the OHP, as they were equipped with many different types of instruments, including varying recording system hardware, power supply, and data format. It was therefore one of the most important tasks of the OHP to unify the total observation system so that each station is of world standard performance. Finally, the OHP seismic network, with 11 broadband stations, was constructed in the western Pacific region (Fig. 2.1.1). Upon completion of the OHP, this seismic network was transferred to the IFREE of JAMSTEC for more efficient long-term operation and cooperative maintenance.

(3) Onland geomagnetic observatories

A network of geomagnetic observatories was constructed during the 6 years of the OHP (Fig. 2.1.1), consisting of nine sites equipped with a geomagnetic system (RFP-523) developed within the OHP and one site in Antarctica (Syowa Station) whose data are provided by the National Institute for Polar Research. RFP-523 provides stable observations for the study of geomagnetic secular variation with a typical baseline drift that is smaller than 5 nT/yr for three components, with only one absolute calibration every year (Shimizu and Utada, 1999). Data from the OHP geomagnetic network have been and will be used to image the 3-D distribution of mantle conductivity. The OHP geomagnetic network is also maintained in collaboration with IFREE/JAMSTEC.

(4) Submarine cable network for measurement of the geo-electric field

Seven submarine cables (one in the Japan Sea and six in the Pacific Ocean) are used for long-term monitoring of the geo-electric field after retirement from telecommunications use. Data exchange protocol exists between the OHP and US research group who run a similar experiment in the eastern Pacific region. One of the goals of this experiment is to constrain the strength and spatial distribution of the toroidal magnetic field at the core surface. Theoretical studies show that a detectable electric signal can be generated by a rapid (decadal scale) oscillation of the outer core fluid that is comparable to observed changes in voltage differences (Shimizu and Utada, 2004). Geo-electric data are also used in 3-D EM tomography and will be used to further investigate mantle conductivity together with geomagnetic data.

(5) Seafloor magnetic observatory

A seafloor instrument was developed within the OHP that enables us nearly permanent observation of four components of the geomagnetic field (three components and total intensity) and two components of the geo-electric field using measurements of the instrument's attitude (orientation and tilt). After 5 years of development, this instrument was deployed at site WP-2 (near the borehole seismic site in the Northwest Pacific Basin) in 2001 and recovered one year later, when an identical instrument was installed for a further year's operation. Our investigation has shown that the repetition of such deployment will provide a continuous magnetogram that is nearly equivalent to that of a standard onland geomagnetic observatory (Toh et al., 2004).

(6) GPS network in the western Pacific

More than 10 continuous GPS observation sites were deployed in the western Pacific region by the OHP, and continuous positioning data from over 40 sites were analyzed as well as campaign results in several areas. As a result, we found that the motion of oceanic plates such as the Pacific and Philippine Sea plates is generally consistent with geological models of plate motion, while the continental plates of Asia is subject to large-scale deformation, mostly due to collision with the Indian subcontinent. We precisely determined the spreading rate of a back-arc basin, the Mariana Trough, which is also consistent with the geologically estimated rate.

(7) Seafloor geodesy

A precise seafloor positioning system was developed in collaboration with the Scripps Institution of Oceanography and installed on both sides of the Japan Trench, off the Sanriku coast, as a test experiment. This system realizes a resolution of horizontal location as high as a few mm at a slant range of 14 km using a GPS-acoustic link; this enables us positioning control for the deep ocean floor at sites such as close to the trench axis. This technology is expected to measure the convergence rate of the Pacific Plate in the vicinity of the trench axis, about 300 km offshore.

(8) Super-conducting gravimetry

The OHP constructed a network of super-conducting gravimeters at Syowa in the Antarctica, Canberra in Australia, Bandong in Indonesia, Esashi in Japan, and Ny-Alesund in Norway. This network is the first in the world that extends from the polar regions, where the Earth's rotation effect is minimum, to the equatorial region where the effect is at a maximum. Analysis of data from this network reveal the coupling between the solid and liquid Earth over a frequency range that is much wider than that considered previously. Long-term measurement in Norway is also expected to detect post-glacial rebound.

2-6. Ocean Hemisphere Network Data Center

The Ocean Hemisphere Project Data Management Center (OHPDMC) was established in 1997 to provide research communities with an easy-to-use data distribution service. The OHPDMC provides seismic, geomagnetic, and geodetic data from the OHP network and other related networks. In addition to these required tasks, we developed a new data distribution system by applying JAVA RMI, a recent IT technology for networked systems (Takeuchi et al., 2002). This system realizes a network data center and provides a unified interface such that a user can download data from various data centers on the Internet.

Following the establishment of IFREE within JAMSTEC, OHPDMC began to closely cooperate with IFREE in running the data center. The OHPDMC plays an important role, especially in real-time data transmission. We have been replacing the observation system since 2002, and seven of ten broadband seismic stations, four of nine geomagnetic stations, and all four submarine cables (measuring voltage differences) are now online. These data are beginning to be applied to a preliminary real-time data analysis (Fig. 2.6.1).

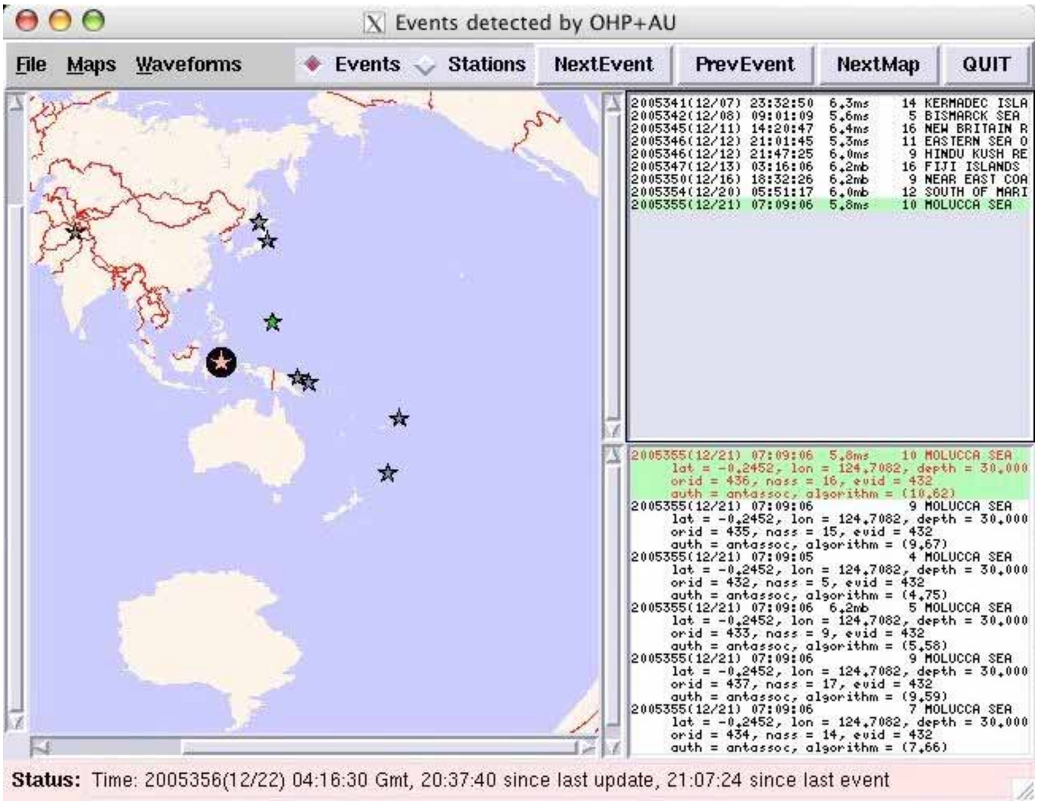
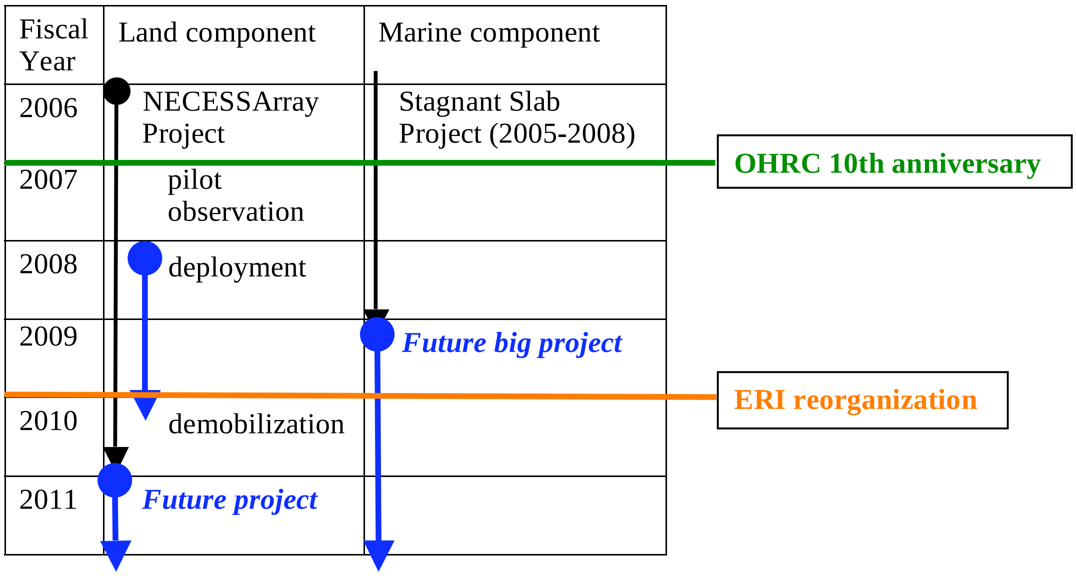


Fig. 2.6.1 Preliminary results of real-time hypocenter determinations obtained using real-time data from the OHP seismic network (Mizutani, 2006, personal communications).

3. Future Plan of Ocean Hemisphere Research Center (OHRC)

As ERI plans to have an institutional reorganization of its research centers and divisions at the end of the 2009 fiscal year (i.e., March, 2010), which coincides with the end of the university's 6-year term, it is our plan to keep OHRC in the present form till then even after the end of its originally planned 10-year period. In the following, we will discuss what our main research focus will be during the extended term of our center (5 years or so). It is our hope that the review committee will evaluate this plan, and gives us advices and/or recommendations, so that we may utilize the resources that we possess in maximum for better understanding of the earth's internal processes.



Seismic and electromagnetic joint ocean-bottom mobile array research:

Through the OHP project, OHRC has established permanent geophysical networks in the western Pacific region, which are now largely maintained by IFREE/JAMSTEC in cooperation with OHRC. In the post-OHP era, our focus has shifted toward more mobile array type observational science, such as one currently performed in the Stagnant Slab project (see Section 2-1-2). In the project, the long-term ocean bottom broadband seismic and electromagnetic observations are conducted together as a team effort for the first time to map out the integrated image of the mantle transition zone beneath the Philippine Sea. We believe that it is OHRC's great strength to be able to conduct such science using our own instruments, and this should be pursued further for the coming decade to make major contribution in the mantle dynamics research. New systems for marine seismic, EM and geothermal observations are under development by individual research program in OHRC. Deployment of these new instruments is expected to lead us to another breakthrough in terms of the quality of observation data.

Although at present we have no definite plan for the next big project after SSP, one of the possible target areas may be the northwestern Pacific, seaward of the Japanese subduction zone, where land-based seismic tomography studies with limited resolution have provided images of a low velocity anomaly around a depth of 400km. Recent geophysical and geological observations have also found fresh volcanoes in the old lithosphere and seismic activities in the middle of the northwestern Pacific. Marine geophysical observations in this region will contribute to improve the resolution of the mantle image and to elucidate the relation among these phenomena. Seismic observations using BBOBSs, electromagnetic observations using OBEMs, and heat flow measurements should be carried out in such regions. The seismic and EM tomography can provide seismic velocity/attenuation and electrical conductivity structure models, respectively, while the heat flow measurements will provide boundary conditions of thermal modeling. Integrated analysis of these data allows us to separate effects of thermal and compositional heterogeneities of the mantle, and helps understanding of the origins of peculiar activities observed.

Following the Stagnant Slab project which ends in FY2008, to pursue the line of research, we hope to get funding by applying for large funding sources such as Monbu Kagakusho's Grants-in-Aid for Scientific Research for "Specially Promoted Research" ("tokubetsu suishin kenkyu").

Land-based mobile broadband seismic array research:

While the ocean-based approach provides the OHRC's unique contribution to the mantle dynamics research, we also plan to strengthen our land-based approach, which provides high quality and large quantity data set. One of such projects is now about to be launched.

NorthEast China Extended SeiSmic Array (NECESSArray) is a passive broadband seismic experiment aiming to reveal the seismic structure beneath the northeastern China, where the Sino-Korea craton and unusual volcanism in the continent are tectonically quite interesting. The structure of the upper mantle is the main target of NECESSArray to clarify the tectonic roots of this interesting and seismologically unexploited area and its relation to the stagnant slab beneath this region. This project may be considered, to some extent, as a land-based component of the Stagnant

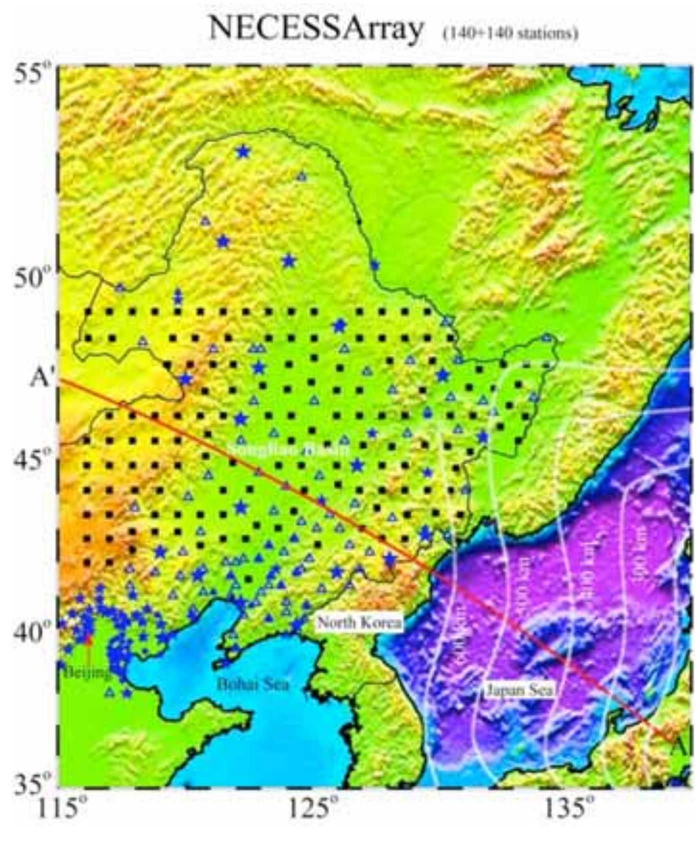


Fig. 3.1. Station of the planned temporary NECESSArray (black squares) are shown together with the permanent stations (some are planned) in China.

Slab project; or at least it will greatly complement the achievements of SSP. NECESSArray runs under the collaboration with the China Earthquake Administration (led by Dr. Y. Chen) and USA scientists (Drs. S. Grand, F.-L. Niu, J. Ni), and OHRC will take the leading role of the Japanese side. 140 mobile broadband stations are planned to be deployed for two years, and with 140 permanent stations of Chinese regional seismic networks, NECESSArray will consists of 280 stations (Fig. 3.1), the scale and density comparable to one foot of the USArray; thus it is a frontier and challenging observational seismology conducted in the best accessible area to study deep subduction processes. Moreover, the experiment will play an important role to image deep mantle structures beneath the western Pacific where the largest cold and hot superplumes are mutually interacting. The investigation in northeast China will be eventually integrated to more institutional project including not only the NECESSArray but also EM, GPS and gravity observations, geochemical and petrological studies, and computer simulations, which are currently conducted rather independently.

As to a future project in this context, we consider a mobile broadband array experiment in Vietnam (see Section 2-2-2; Fig. 2.2.10), where we currently operate 6 stations, as a potential target. Vietnam is located near the antipode of the south America where deep seismicity is high, and thus this array will greatly improve our knowledge of the deepest part of the inner core which is least known in this planet.

It is our plan as a center to spend resources available to OHRC mainly to these lines of research, while keep conducting other research activities discussed in Section 2 of this report. For the purpose, we plan to apply for funding supports from various external agencies, and also hope to receive financial and personnel support from the institute.

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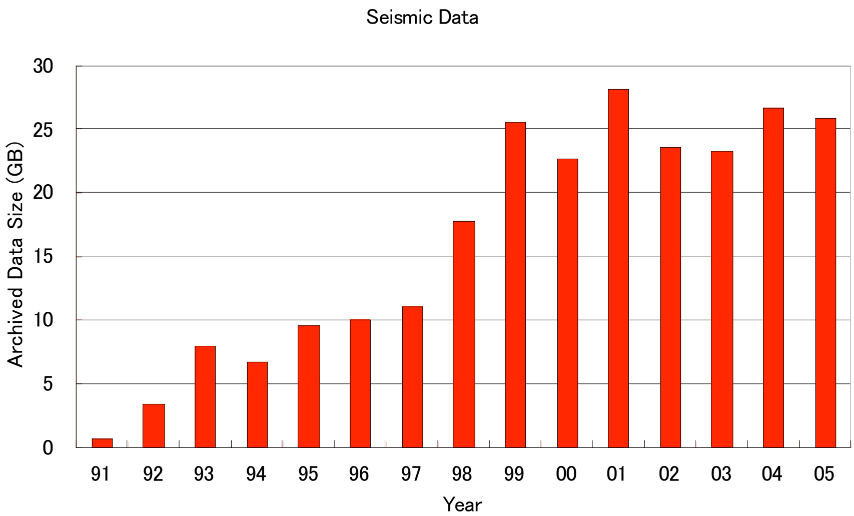
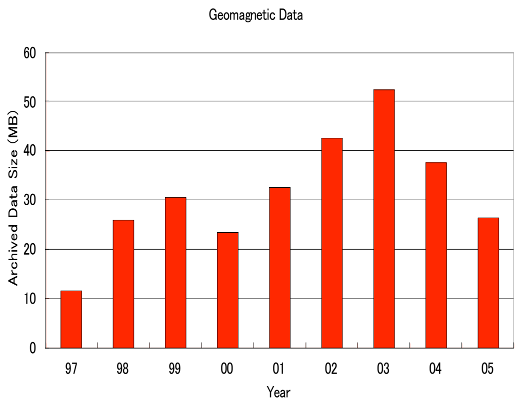
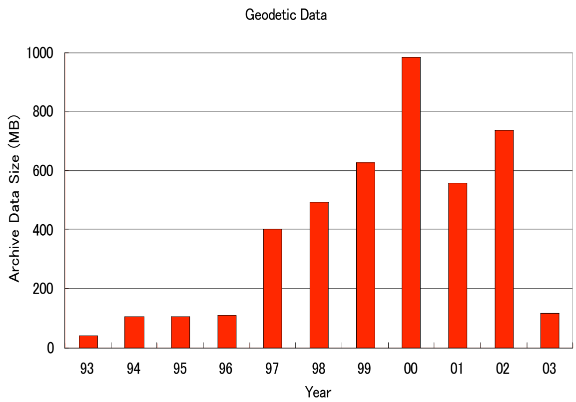
資料 2. データセンター(OHPDMC)におけるデータアーカイブ状況

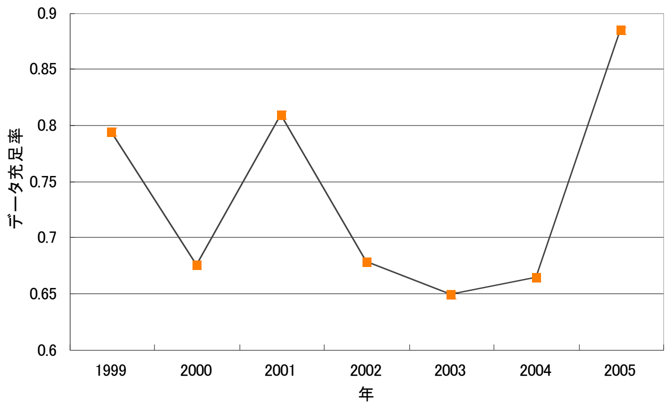
〈データアーカイブ量の年度別変遷〉 (2005 年データは一部未回収)







＜データ充足率（地震データ）の年度別変遷＞ (データ充足率＝１－欠測率)



(2005 年 1 月より新リアルタイムデータ収集システムの本格稼働開始)

資料 3. 外部資金獲得状況 （1997 年度以後）

科学研究費

種目	年度	課題番号	研究代表者	研究課題	金額（万円）
学術創成研究費	1996〜2001	09NP1101	深尾 良夫	海半球ネットワーク：地球内部を覗く新しい目	73700
基盤(A)	1997〜2000	9304043	川勝 均	阿蘇山の火口直下に存在する圧力源の実体と噴火活動における役割の解明	3450
基盤(A)	1995〜1997	7504005	山野 誠	海底ケーブル式長期計測装置用非接触型カプラーの開発	3340
基盤(B)	1996〜1997	8300001	深尾 良夫	地震予知・火山噴火予知研究の総合評価及び今後のあり方に関する調査研究	750
基盤(B)	1996〜1997	8454119	深尾 良夫	固体− 流体系としての地殻の単色振動現象	760
基盤(B)	1997〜1998	9554021	森田 裕一	火山及び活断層観測用高密度地殻変動観測システムの開発	1080
基盤(B)	1995〜1997	7454101	山野 誠	自己浮上式海底熱流量計による西南日本沈み込み帯の熱的構造の研究	790
基盤(C)	1996〜1997	8640523	歌田 久司	海底における長期地磁気観測のための基礎研究	180
国際学術	1997〜1998	9041097	深尾 良夫	ペルーアンデスの重力分布と堆積層調査に基づく山脈隆起の研究	1340
基盤(B)	1998〜2000	10440125	深尾 良夫	水中音波・水中多重反射波のアレー観測に基づく海底地殻活動のモニタリング	1300
奨励(A)	1998〜1999	10740215	飯高 隆	変換波・反射波を用いた上部・下部マントルのＳ波偏向異方性領域の研究	170
基盤(C)	1999〜2000	11640406	歌田 久司	地球電場に関する基礎研究	210
萌芽	1999〜2000	11874060	深尾 良夫	直交光路レーザー干渉計による地球自由振動帯域の剪断歪直接測定	210
奨励(A)	1999〜2000	11740256	綿田 辰吾	微気圧・精密海洋底水圧観測に基づく常時地球自由振動の励	130

				起源の探求	
基盤(B)	2000〜2002	12554014	歌田 久司	群列時間領域電磁法による火山体内部の状態監視システム（ACTIVE）の開発	1380
基盤(B)	2000〜2002	12558042	川勝 均	地震波動場のモニタリングによるリアルタイム地震解析システム	1370
基盤(B)	2000〜2002	12573004	歌田 久司	アジア大陸東縁部の上部マントル電気伝導度構造の研究	980
奨励(A)	2000〜2001	12740257	竹内 希	広帯域波形インバージョンによる３次元地球内部構造及び減衰構造の同時推定	200
基盤(A)	2001〜2003	13304034	深尾 良夫	常時大気自由振動の検出と地球・大気系常時自由振動論の展開	4632
奨励(A)	2001	13740265	綿田 辰吾	高地における微気圧観測による常時自由振動励起源としての大気振動の直接検出	220
若手(B)	2001〜2002	13740264	清水 久芳	地球流体核内の小スケール流によって生成されるα効果に関する理論的研究	200
基盤(A)	2002〜2004	14204041	歌田 久司	地球電場の観測的研究	3700
基盤(B)	2002〜2004	14340130	金沢 敏彦	自己埋設方式広帯域海底地震計の開発による海域地震研究の新展開	1520
基盤(C)	2002	30220073	森田 裕一	ディジタル・フィードバック地震計実用化のための基礎研究	340
基盤(A)	2003〜2007	15204040	川勝 均	火山流体のモニタリングと深部マグマ上昇メカニズムの解明	3220
基盤(B)	2003〜2005	15403006	歌田 久司	スタグナント・スラブの電気伝導度	820
基盤(C)	2003〜2004	15540404	綿田 辰吾	微気圧・広帯域地震同時アレイ観測による長周期地動励起源としての大気圧変動の研究	390
特定領域	2003〜2004	15038205	綿田 辰吾	広帯域音波観測に基づく火山爆発に伴う空気振動の研究	480
特定領域	2004〜2008	16075204	歌田 久司	海底電磁気機動観測でスタグナントスラブを診る	16750

特定領域	2004ー2008	16075203	金沢 敏彦	海底広帯域地震観測でスタグナントスラブを診る	40770
基盤(B)	2004ー2006	16340126	山野 誠	浅海域における熱流量測定による南海トラフ地震発生帯の温度構造の研究	1650
基盤(C)	2004ー2005	16540378	塩原 肇	マリアナでの日米合同海陸長期地震観測による背弧域地下構造の解明	260
特定領域	2004	16029203	綿田 辰吾	常時地球自由振動データ解析に基づくmHz帯域重力波の探索の新展開	120
若手(B)	2004ー2006	16740249	竹内 希	新世代地震計網データ解析手法開発による次世代内部構造モデル推定	330
基盤(C)	2005ー2007	17540391	市原 美恵	マグマ破壊特性の定量化と計測手法開発を目指した模擬物質の破壊実験	360
特定領域	2005ー2006	17037007	馬場 聖至	電気伝導度異方性で見るフィリピン海上部マントルダイナミクス	80
萌芽	2005ー2006	17654086	清水 久芳	地球ダイナモモデルの計算法の開発：核‐ マントル境界における境界条件の検討	100

科学研究費採択件数（学術創成研究費を除く）

年度	海半球観測研究センター		地震研究所全体	
	新規	継続	新規	継続
1997	3	5	21	15
1998	2	3	13	21
1999	3	3	20	15
2000	4	5	21	22
2001	3	4	17	26
2002	3	5	25	27
2003	4	3	25	25
2004	6	6	26	39
2005	3	7	19	30

外国人特別研究員奨励費

年度	研究代表者	研究課題	金額 (万円)
1997〜1998	川勝 均 (Niu, F.)	広帯域地震計データによる西太平洋地域のマントル構造の地震学的研究	210
1998	深尾 良夫 (Widiyantoro, S.)	Ｓ波走時データと表面並波形データの同時インバージョンに基づくマントルＳ波構造	120
1998〜1999	深尾 良夫 (Gorbatov, A.V.)	グローバル/リージョナル非線形走時トモグラフィーによる沈み込み帯の深部構造の研究	240
2000	深尾 良夫 (Martcehnkov, A.)	ロシア極東、カムチャッカ地域の地震テクトニクスの研究	120
2000〜2002	歌田 久司 (Gnsane, O.)	地下洞における岩石および気圧の関係：地震電磁気現象と環境保全への応用	200
2001〜2002	歌田 久司 (Tang, J.)	中国東北部および日本列島を含む西太平洋の沈み込み帯の電気伝導度構造の研究	110
2005〜2007	山野 誠 (Harcouet, V.M.)	南海トラフ沈み込み帯における地震発生帯の温度構造と力学的な性質についての研究	110

日本学術振興会

事業	年度	研究代表者	研究課題	金額 (万円)
日米協力	1997	深尾 良夫	北西太平洋沈み込み帯付近の上部マントル遷移層に関する地震学的構造解析	327.6
日米科学協力	2000〜2001	歌田 久司	太平洋のマントルの電気伝導度構造に関する研究	265
日豪協力	2001〜2002	深尾 良夫	西太平洋及びオーストラリア大陸のマントル構造	368
アメリカ合衆国、オーストラリア、および欧州諸国との共同研究	2004〜2006	歌田 久司	太平洋のマントル電気伝導度に関する研究	430

受託研究

委託者	年度	研究担当者	研究課題	金額(万円)
郵政省通信総合研究所	1994〜1998	歌田 久司	海底ケーブルを用いた地磁気誘導電圧観測技術の開発	750
工業技術院地質調査所	1999〜2000	飯高 隆	西太平洋沈みこみ帯構造の解明による「スーパーコールドプルーム」の研究	504.3

共同研究

相手機関	年度	研究担当者	研究課題	金額(万円)
海洋科学技術センター	2001	歌田 久司	機動的長期アレイ観測によるマントル上昇流と下降流の実態解明	2350
海洋科学技術センター	2002〜2003	歌田 久司	太平洋におけるグローバル地球物理観測による地球内部の構造とダイナミクスの解明	5520

奨学寄付金

寄付者	年度	研究担当者	金額(万円)
(株)テラ	1998	歌田 久司	50

資料 4. センター構成員

教職員

センター長：	深尾良夫（平成9〜12年度） 歌田久司（平成13〜16年度） 川勝　均（平成17年度）
教授：	歌田久司，川勝　均，深尾良夫（平成9〜15年度） 金澤敏彦（併任，平成12年度〜）
助教授：	塩原　肇（平成11年度〜），森田裕一（平成9〜15年度），山野　誠
助手：	飯高　隆（平成9〜12年度），市原美恵（平成15年度〜），清水久芳 竹内　希（平成11年度〜），馬場聖至（平成17年度〜），綿田辰吾
技術専門職員：	松嶋信代（情報処理室）
研究支援推進員・技術補佐員：	横山景一（平成16〜17年度）

外国人客員教員

平成 9（1997）年度	田島文子（米国，テキサス大学オースティン校） Vinnnik, Lev Pavlovich（ロシア科学アカデミー地球物理研究所）
平成 10（1998）年度	谷本俊郎（米国，カリフォルニア大学サンタバーバラ校） Grand, Stephen（米国，テキサス大学オースティン校）
平成 11（1999）年度	Bina, Craig R.（米国，ノースウェスタン大学） Vinnnik, Lev Pavlovich（ロシア科学アカデミー地球物理研究所） Kao, Honn（台湾，中央研究院地球科学研究所）
平成 12（2000）年度	高　原（中国地震局預報中心） 鄭　斯華（中国地震局預報中心） Edwards, Richard Nigel（カナダ，トロント大学）
平成 13（2001）年度	趙　國澤（中国地震局地質研究所） Hilde, Thomas W.C.（米国，テキサス A&M 大学） Mjelde, Rolf（ノルウェー，ベルゲン大学）
平成 14（2002）年度	Kuvshinov, Alexei（ロシア科学アカデミー地球電磁気研究所） Stephen, Ralph A.（米国，ウッズホール海洋研究所）
平成 15（2003）年度	Wang, Kelin（カナダ，地質調査所太平洋地球科学センター） Avdeev, Dmitry B.（ロシア科学アカデミー地球電磁気研究所） Ramesh, Durbha S.（インド，国立地球物理研究所）
平成 16（2004）年度	Forte, Alessandro M.（カナダ，西オンタリオ大学） Nguyen, Dung Quoc（ベトナム科学アカデミー地球物理研究所） Harinarayana, Tirumalachetty（インド，国立地球物理研究所）
平成 17（2005）年度	Niu, Fenglin（米国，ライス大学） Ramesh, Durbha S.（インド，国立地球物理研究所） Palshin, Nick A.（ロシア科学アカデミーシルショフ海洋研究所）

国内客員教員

平成 9（1997）年度　　佐野　修（山口大学工学部）
　　　　　　　　　　　堀　貞喜（防災科学技術研究所）

平成 11（1999）年度　小平秀一（海洋科学技術センター）

平成 13（2001）年度　久家慶子（京都大学大学院理学研究科）

平成 16（2004）年度　深尾良夫（海洋研究開発機構）
　　　　　　　　　　　小原一成（防災科学技術研究所）

平成 17（2005）年度　深尾良夫（海洋研究開発機構）

研究員・大学院生

平成 9（1997）年度

外国人研究員：　D. Legrand
COE 研究員：　大林政行
日本学術振興会外国人特別研究員：
　　鈕　鳳林
日本学術振興会特別研究員
　　望月将志，渡辺智毅，小屋口康子，後藤忠徳
大学院生：　博士課程 5 名，修士課程 2 名

平成 10（1998）年度

外国人研究員：　D. Legrand
COE 研究員　大林政行，小屋口康子
日本学術振興会外国人特別研究員：
　　A. Gorbatov，鈕　鳳林，S. Widiyantoro
日本学術振興会特別研究員：
　　藤井郁子，望月将志，渡辺智毅
大学院生:　博士課程 7 名，修士課程 4 名

平成 11（1999）年度

COE 研究員：　加藤　護，小屋口康子，多田　卓，望月将志
日本学術振興会外国人特別研究員：
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大学院生:　博士課程 7 名，修士課程 3 名

平成 12（2000）年度

COE 研究員：　加藤　護、望月将志
日本学術振興会外国人特別研究員：
　　A. U. Marchenkov
日本学術振興会特別研究員：
　　市来雅啓，小林励司
大学院生:　博士課程 7 名，修士課程 4 名

平成 13（2001）年度
日本学術振興会外国人特別研究員：
O. Gensane, Tang J.
日本学術振興会特別研究員：
西田　究
IFREE 研究員：　市来雅啓，馬場聖至
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後藤秀作
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平成 14（2002）年度
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O. Gensane, Tang J.
地震研究所外来研究員：
市来雅啓，小山崇夫
地震研究所特別研究員：
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大学院生:　博士課程 3 名，修士課程 3 名
地震研究所研究生：1 名

平成 15（2003）年度
日本学術振興会外国人特別研究員：
Siripunvaraporn W.
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Shi X.-M.
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平成 16（2004）年度
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