R003-01
D 会場 ：9/25　 PM1 （13:45-15:30）
13:45〜14:00

金属鉱物探査のための岩石電気物性の測定とデータベース化

#高倉　伸一 [1)]
[(1] 産総研

Measurement and database of rock electrical properties for metallic mineral exploration

#Shinichi Takakura[1)]
[(1]Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology（AIST)

Exploration and development of metallic minerals in shallow underground areas is almost complete, and the exploration is shifting to blind deposits in deeper underground areas. Therefore, there are growing expectations for geophysical surveys that can obtain a wide area of deep geological structures nondestructively. Electrical and electromagnetic prospecting is one of the most powerful tools for metallic mineral exploration because of the difference in electrical properties of metal ores and surrounding rocks. Although electrical and electromagnetic surveys provide information on the distribution of electrical properties such as resistivity and chargeability, the interpretation of geological structures from these data is often inadequate. This may be due to a lack of knowledge about the electrical properties of the ores and rocks. Therefore, we are measuring the electrical properties of rocks and compiling a database of such properties for the purpose of metallic mineral exploration.

In general, the geological structure around metal deposits is complex, and the ore distribution area is often narrow. In addition, the areas around the deposits are often subject to mineralization and hydrothermal alteration. It is necessary to understand the electrical properties of rocks around the deposits to interpret the results of electrical and electromagnetic exploration. Therefore, the samples to be measured for electrical properties were a variety of rocks around the deposit. To understand resistivity and IP phenomena, complex resistivity was basically measured over a wide frequency band, and time-domain IP measurements were also performed for some ores to determine the chargeability. In addition, density, porosity, and magnetic susceptibility were also measured at the same time to help interpret the electrical properties. The data obtained was compiled in a database to enable comparison and examination of mineral and rock types and deposit types. In addition, information such as geological and mineralogical descriptions and chemical analysis values of the measured samples were collected as much as possible to build a practical database. This study was a part of the fiduciary obligation project supported by Ministry of Economy, Trade and Industry (METI) in FY2019 and FY2020.

地下浅部にある金属鉱物の探査・開発はほぼ終わっており、探査の対象は地下深部の潜頭性鉱床に移りつつある。そのため、地下深部の地質構造を広域に非破壊で調査する物理探査への期待が高まっている。なかでも電気・電磁探査法は、金属鉱石が周辺の岩石と電気物性が異なることから、金属鉱物調査の強力なツールの一つになっている。電気・電磁探査法からは比抵抗や充電率のような電気物性の分布が得られるが、そこから地質構造を解釈して、有用な金属鉱物を評価するとなると不十分なところが多い。その原因して、地下構造を形成する鉱石や岩石の物性に関する知識が不足していることがあげられる。そこで、我々は金属鉱物探査を目的として、岩石の電気物性の測定やそのデータベース化を実施している。

一般に金属鉱床の周辺の地質構造は複雑であり、鉱石の分布域は狭いことが多い。また、鉱床周辺は鉱化変質や熱水変質を受けていることも多い。したがって、電気・電磁探査結果を解釈には鉱床周辺に分布する岩石の電気物性の把握が必要である。そのため、電気物性測定を行う試料は、鉱床周辺に分布する多様な岩石を対象とした。比抵抗や IP 現象の把握のため、基本的に広い周波数帯域での複素比抵抗を測定し、鉱石によっては充電率を求めるために時間領域 IP 法の計測も実施した。また、電気物性の解釈に役立てるため、密度、間隙率、帯磁率などの測定も同時に行った。得られたデータは、鉱物や岩石の種類や鉱床タイプなどの比較・検討ができるようにデータベース化した。さらに、実用的なデータベースとするため、測定試料の地質学・鉱物学的記載や化学分析結果などの情報もできる限り収集した。本研究の一部は、経済産業省の令和元年度および 2 年度の委託事業「鉱物資源開発の推進のための探査等事業（資源開発可能性調査)」で実施された。

R003-02
D 会場 ：9/25　 PM1 （13:45-15:30）
14:00～14:15

単純 2 次元構造に対する MT 応答関数の理論解の導出 (1)：大気の絶縁近似による TM モード解

#小河　勉 [1)]
[(1] 東大・地震研

The MT response function for a simple 2-D structure(1): TM mode with insulating air approximation

#Tsutomu OGAWA[1)]
[(1]Earthquake Research Institute, the University of Tokyo

When we start learning the magnetotelluric method, its simplest inhomogeneous structure of the electrical conductivity which we assume and discuss is a stratified 1-D 2-layer structure in a half space. We learn the period dependency of the apparent resistivity and the phase via the sounding curves. Those responses for multiple layer structures can be speculated based on the understandings of the 1-D 2-layer problem, though the responses can explicitly be expressed mathematically.

The present study aims to construct such basic understanding for a simplest 2-D conductivity structure. One of simplest 2-D structures which the present study treats is a combination of two homogeneous conducting quarter spaces composing a half space.

As is already well known, the electromagnetic fields for 2-D cases are separated into two modes: the transverse magnetic (TM) and the transverse electric (TE) modes. The responses for the TM mode with an approximation that the air is fully insulating is presented. The responses can explicitly be expressed mathematically with an integral transform, while for the TM mode without the approximation and for the TE mode the responses cannot be expressed explicitly: the ratio of functions derived from the solution of integral equations of electromagnetic fields. Since the present problem lacks a spatial scale of the structure which is the thickness of the shallower layer for the 1-D 2-layer problem, the distance from the boundary between the two quarter spaces becomes the spatial scale.

The derived sounding curves and pseudo-sections, together with some theorems and their quantitative discussions are presented.

我々が MT 法の学習を開始する際に、最初に想定し議論する電気伝導度不均質構造は半無限空間の 1 次元 2 層成層構造である。探査曲線を用いて、見かけ比抵抗と位相の周期依存性を学習する。1 次元多層成層構造の MT 応答関数は、陽に記述することが可能であるが、我々には 2 層成層構造の MT 応答関数に対する理解にもとづいて推測することも可能である。

本研究は、1 次元多層成層構造の MT 応答関数に関するこのように基本的な理解を、単純な 2 次元構造に対して構築することを目指している。本研究で電磁場の算出のために扱う、最も単純な 2 次元構造の一つは、2 つのそれぞれ均質な四半無限空間の組み合わせによる半無限空間である。

既によく知られている通り、2 次元空間における電磁場は TM モードと TE モードとに分離される。本発表では、大気を絶縁体に近似した際の TM モードの MT 応答関数について示す。この近似のもとでは MT 応答関数は積分変換を用いて解析解の陽な表現が可能である。このような陽的表現は、大気を絶縁近似しない TM モードと、TE モードとにおいては得られず、電磁場が満たす積分方程式の解に由来する関数の比となる。1 次元 2 層成層構造の場合には 1 層目の厚さが空間スケールの基準になるのに対して、本研究の問題設定における空間スケールの基準は、四半無限空間の境界から観測点までの距離となる。

解析解から得られた探査曲線と疑似断面、いくつかの定理の定量的な議論を本発表では示す。

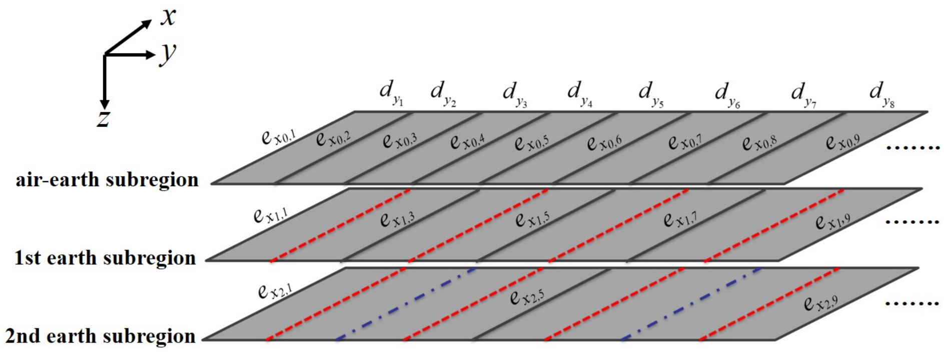
R003-03
D 会場 ：9/25　PM1 （13:45-15:30）
14:15〜14:30

#Li　Jian[1,2],Liu Jianxin[1],Ogawa　Yasuo[2,3],Guo Rongwen[1],Wang Xulong[1],Xu Jingdao[1],Wang Yongfei[1]
[1] セントラル・サウス大学,[2] 東工大,[3] 東工大

An efficient algebraic multi-resolution sampling approach to 3-D magnetotelluric modelling

#Jian Li[1,2],Jianxin Liu[1],Yasuo Ogawa[2,3],Rongwen Guo[1],Xulong Wang[1],Jingdao Xu[1],Yongfei Wang[1]
[1]School of Geosciences and Info-Physics, Central South University,[2]Institute of Innovative Research,Tokyo Institute of Technology,[3]Tokyo Institute of Technology

Since electromagnetic (EM) fields diffuse more smoothly to greater depth, it physically makes sense to apply fine discretization to model structure at near surface with an increasingly coarser grid both in horizontal and vertical directions as the depth increases for the numerical solution of EM fields. For finite-difference magnetotelluric (MT) forward modelling on regular staggered grids, this can lead to difficulties in discretizing the curl − curl equation governing the EM diffusion in the earth at regions, where the grid resolution changes. In this paper, we propose an efficient algebraic multi-resolution sampling (MRS) method for MT forward modelling. In this method, we do not require the generation of physical subgrids and merely subsample the field components. The coefficient matrix for the subsampled components can be obtained by matrix multiplication based on the initial linear system of equations and field interpolation. To guarantee divergence-free current during the iterative solution process at low frequencies, which is considered crucial for the development of ef ficient iterati v e solv ers, our forward modelling is based a regularization equation obtained by augmenting the curl − curl equation with an equi v alent scaled grad − div operator for electrical fields (explicitly enforcing the divergence-free condition). The correctness of our algebraic MRS algorithm is examined based on a layered model. Its stability and efficiency is exploited by comparing our results with the forward modelling on unsampled staggered grids for the Dublin Test Model 1 (DTM1) and a complex model with realistic topography, indicating a time reduction of about 42 − 82 percent.



R003-04
D 会場 ：9/25　 PM1 （13:45-15:30）
14:30〜14:45

#南　拓人 [1)]
[(1] 神戸大理

Development of 3-D joint inversion code for MT and CSEM data sets for both land and ocean survey situations

#Takuto Minami[1)]
[(1]Graduate School of Science, Kobe University

There have been increasing opportunities to use controlled-source electromagnetic (CSEM) data together with conventional MT data, to accurately infer subsurface resistivity structures. I have developed a 3-D joint inversion code that simultaneously handles MT data sets and CSEM data sets. The forward part is designed using the edge-based finite element method for unstructured tetrahedral meshes, while the inversion part consists of the Gauss-Newton approach with a cooling strategy (e.g., Kordy et al., 2016). Since the forward part of CSEM is applicable to any source distribution of source electric dipole, the developed code deals not only with conventional CSEM like ACTIVE (Utada et al., 2007) but also with tide-generated magnetic variation (Nakaya et al., 2022, SGEPSS). In the presentation, I will report the details of the developed joint inversion code and its applications to the case of Aso volcano, where ACTIVE (Utada et al., 2007) is intermittently operated, as well as AMT surveys (Kanda et al. 2019). I will also discuss its application to the case of the Lau basin, where tidally-induced magnetic field data provide sensitivity to the upper mantle resistivity (Nakaya et al., 2022, SGEPSS).

R003-05
D 会場 ：9/25　 PM1 （13:45-15:30）
14:45～15:00

#宋　晗[1,2], 上嶋　誠[1],YU Peng[2], 臼井　嘉哉[1], ディバ　ディエノ[1],ZHANG Luolei[2],ZHAO Chongjin[2],HUANG Zuwei[2]
([1] 東大・震研,([2] 同済大·海洋地質国家重点研

Integrated interpretation of structure around the Atotsugawa Fault by MT, Magnetic, and Gravity inversion with seismic constraint

#Han SONG[1,2],Makoto Uyeshima[1],Peng YU[2],Yoshiya Usui[1],Dieno Diba[1],Luolei ZHANG[2],Chongjin ZHAO[2],Zuwei HUANG[2]
([1]Earthquake Research Institute, the University of Tokyo,([2]State Key Laboratory of Marine Geology, Tongji University, Shanghai, China

Different geophysical methods provide information about various physical properties of underground structures and rock formations. In many situations, this information is mutually complementary. One can reduce the inherent uncertainty and ambiguity of single geophysical inversion and interpretation by utilizing this complementary information. The key productive approaches to achieving this target are joint multi-geophysics inversion and constrained inversion steered (or guided) by highly reliable geophysical structural models of other kinds. In this research, we apply the joint and constrained ideas together to study the structure around the Atotsugawa Fault in central Japan, especially for the origin of the aqueous fluid in the lower crust, as well as the association of the deep fluid with the Philippine Sea slab and the Pacific slab beneath the Atotsugawa Fault. Previously, a resistivity structure was obtained from an EM (MT and NMT) only inversion (Usui et al., 2021). Here, our inversion uses the same MT and NMT datasets but jointly with satellite Magnetic (Maus et al., 2009) and Gravity data (Sandwell et al., 2014) and is steered by pre-existing seismic velocity structure (Matsubara et al., 2022). The coupling method we use to connect different physical models is cross-gradient coupling (e.g., Gallardo and Meju, 2003), which enforces the structural similarity between different physical models. The technical framework that joint inverts MT, Gravity, and Magnetic data with seismic constraints will be discussed in this presentation, as well as corresponding electrical, magnetization, and density resulting models and their geological meanings.

R003-06
D 会場 ：9/25　 PM1 （13:45-15:30）
15:00～15:15

MC-NMF に基づいた MT 探査データ中のノイズ評価の試み

#天野　玲 [1), 後藤　忠徳 [1), 吉村　令慧 [2)
[(1] 兵庫県立大学,[(2] 京大・防災研

Attempt of noise evaluation of MT data based on MC-NMF

#Rei Amano[1)],Tadanori Goto[1)],Ryokei Yoshimura[2)]
[(1]University of Hyogo,[(2]Disaster Prevention Research Institute, Kyoto University

The magnetotelluric (MT) is one of the electromagnetic survey methods for the estimation of deep subsurface structures by observing natural fluctuations of geomagnetic and electric fields. It is known to be difficult to obtain high quality data when there is strong artificial noise in the survey area. However, it has not been fully discussed how the noise amount in the electromagnetic field data varies over time and space when the MT method is performed.

This study applies MC-NMF (Multi-Channel Nonnegative Matrix Factorization), one of the matrix factorization methods to time-series data (five stations) obtained from the MT method conducted in the Noto Peninsula and data from the Kakioka Magnetic Observatory at the same time. Earthquake swarms have been occurring in the Noto Peninsula since around 2018. The amount of noise in each observation condition was estimated by comparing the basis vectors of the Noto Peninsula data and the Kakioka data, which were decomposed by MC-NMF. Besides, we also compared the noise amount obtained with singular value decomposition, which is also a matrix decomposition method.

The results showed the usefulness of using MC-NMF to estimate the amount of noise. The characteristics of space-time variation in the noise amount could also be captured.

地磁気地電流法 (Magnetotelluric:MT) 法は、自然に発生した地磁気と地電流を観測して
地下深部の構造を推定する電磁探査法である。MT 法を行う調査域の人工ノイズが強い場合は良質なデータ取得が難しいことが知られている。しかしながら、MT 法を行った観測地点・時間帯に
よって、得られる電磁場データ中のノイズの大きさがどのように時空間変動するかについては十分には議論されていない。

本研究では、2018 年頃から群発地震が発生している能登半島において行われた MT 探査で得られた時系列データ (5 地点）と同時刻の柿岡地磁気観測所のデータに対して、行列分解の手法の一つである MC-NMF(Multi-Channel Nonnegative Matrix Factorization) を適用し電磁場変動を
多数の成分に分離した。MC-NMF で分解した能登半島のデータの基底ベクトルと柿岡のデータの基底ベクトルを比較することによって、各観測における条件ごとのノイズ量を推定した。これとは別に、同じく行列分解手法の一つである特異値分解で求めたノイズ量との比較も行った。

その結果、MC-NMF を用いてノイズ量を推定することの有用性を示すことができた。また、能登半島で発生しているノイズの時空間変化の特徴を捉えることができた。

R003-07
D 会場 ：9/25　 PM2 （15:45-18:15）
15:45～16:00

MT 法比抵抗探査による支笏カルデラのマグマ供給系の解明

#山谷　祐介 [1), 山際　嵩也 [2), 鈴木　浩一 [2), 茂木　透 [2), 橋本　武志 [3)
[(1] 産総研・再生可能エネルギー研究センター,[(2] 北大・工,[(3] 北大・理・地震火山研究観測センター

Magnetotelluric resistivity study targeting magma supply system of Shikotsu Caldera, Hokkaido, Japan

#Yusuke Yamaya[1)],Takaya Yamagiwa[2)],Koichi Suzuki[2)],Toru Mogi[2)],Takeshi Hashimoto[3)]
[(1]National Institute of Advanced Industrial Science and Technology（AIST),[(2]Faculty of Engineering, Hokkaido University,[(3]Institute of Seismology and Volcanology, Faculty of Science, Hokkaido University

The Shikotsu caldera located in southwestern Hokkaido was formed approximately 40,000 years ago by a catastrophic eruption accompanied by large-volume pyroclastic flows. Subsequently, post-caldera volcanoes such as Mts. Tarumai, Fuppushi-dake, and Eniwa-dake erupted at the caldera rim. Mts. Tarumai and Eniwa-dake are active volcanoes that are characterized by seismicity including low-frequency events at depth and continuous fumarolic activity. Using the magnetotelluric method in the Ishikari lowland zone, Yamaya et al. (2017) estimated a remarkable conductive body at depths greater than 10 km beneath the Shikotsu caldera. This conductor implied the migration path and reservoir of magmatic fluid because the conductor extended to the depth of the Moho, and the hypocenters of low-frequency earthquakes were distributed nearby the conductor. However, its location and shape remained uncertain because the conductive structure was located at the edge of the observation area in the previous study. We conducted additional MT measurements at 12 sites in August-September 2021 to clarify the magma plumbing system of the Shikotsu caldera and the post-caldera volcanoes such as Tarumai. The ADU-07e systems measured a time series of two electric field components and three magnetic field components at all sites for over five days. We processed the data using the BIRRP code (Chave and Thomson, 2003) with the far remote-reference data at Okura Village, Yamagata Prefecture, about 450 km from the study area. The calculated apparent resistivity, phase, and magnetic transfer functions were generally consistent with the pre-existing data. We started preliminary three-dimensional inversion modeling with the aid of the FEMTIC code (Usui, 2015) based on the data at 55 sites in total. Although the smoothing parameters have not yet been optimized at the time of abstract submission, we have confirmed that some important features, such as the regionally-distributed conductive sedimentary layer and the remarkable conductor beneath the Shikotsu caldera, are in agreement with our previous studies.

R003-08
D 会場 ：9/25　PM2 （15:45-18:15）
16:00〜16:15

#渡部　熙 [1], 上嶋　誠 [1], 山口　覚 [2], 臼井　嘉哉 [1], 村上　英記 [3], 小河　勉 [1], 大志万　直人 [4], 吉村　令慧 [4], 相澤　広記 [5], 塩﨑　一郎 [6], 笠谷　貴史 [7]
([1] 東大地震研,([2] 大阪市大院・理・地球,([3] 高知大,([4] 京大・防災研,([5] 九大地震火山センター,([6] 鳥取大院,([7] 海洋研究開発機構

The 3-D electrical conductivity structure modelling of the Network-MT observation dataset in the Kii Peninsula, southwestern Japan

#Akira Watanabe[1],Makoto Uyeshima[1],Satoru Yamaguchi[2],Yoshiya Usui[1],Hideki Murakami[3],Tsutomu OGAWA[1],Naoto Oshiman[4],Ryokei Yoshimura[4],Koki Aizawa[5],Ichiro shiozaki[6],Kasaya Takafumi[7]
([1]Earthquake Research Institute,The University of Tokyo,([2]Graduate school of Science, Osaka City University,([3]Kochi University,([4]Disaster Prevention Research Institute, Kyoto University,([5]Institute of Seismology and Volcanology, Faculty of Sciences, Kyushu University,([6]Graduate school of Science, Tottori University,([7]JAMSTEC

The Kii Peninsula in the forearc region of southwest Japan has distinct structural and tectonic features characterized by the subducting Philippine Sea slab, high seismicity in the crust, Deep Low-frequency Tremors (DLTs), high surface heat flow, and high-temperature hot springs. Therefore, various geophysical surveys have been carried out on the Peninsula, including electromagnetic surveys. Some conventional MT surveys (NEDO 1994; Fuji-ta et al., 1997; Umeda et al., 2003; Kinoshita et al., 2018) and the Network-MT (NMT) survey (Yamaguchi et al., 2009) have been performed. The NMT method (Uyeshima et al., 2001; Uyeshima, 2007) is characterized by employing a commercial telephone network to measure voltage differences with long dipole lengths ranging from 10 to several tens of kilometers. This method has three advantages; the first is wide spatial coverage (e.g., covering almost the entire Kii Peninsula), the second is a wide-period range, especially for the longer period (from 10 s to 50000 s), and the third is better quality data in terms of high S/N ratio and less susceptibility to static effects. Yamaguchi et al. (2009) deployed the NMT survey at 55 nets throughout the Kii Peninsula. One net consists of 3-5 channels with 4-6 electrodes, and we measured respective voltage differences at 10 s intervals for 50-400 days. Magnetic fields were also measured at three stations in the survey area. Using this data, Yamaguchi et al. (2009) showed a 2-D resistivity structure along a line crossing the central part of the Kii Peninsula. However, a 3-D model analysis is necessary to reveal the regional and deep structure of this region because the coastline and bathymetry are 3-D, and the strike of the igneous rocks (the Kumano acidic rocks) is not concordant with the direction of the subducting Philippine Sea slab. Prior to determining the final 3-D model, we reanalyzed whole NMT data obtained by Yamaguchi et al. (2009) using the BIRRP code (Chave and Thomson, 2004) and calculated the first 3-D electrical resistivity structure model using the Network-MT datasets. In this inversion analysis, the FEMTIC inversion code (Usui, 2015; Usui et al., 2017; Usui, 2020) was used. In this presentation, we show a resultant resistivity structure and compare it with the spatial distribution of the NMT response functions and other geophysical models.

R003-09
D 会場 ：9/25　 PM2 （15:45-18:15）
16:15〜16:30

ニュージーランド Inferno Crater Lake における EM-ACROSS 連続観測

#北岡　紀広 [1), 小川　康雄 [2),T. Grant　 Caldwell[3), 石須　慶一 [4), 南　拓人 [5),Alison　 Kirkby[3)
[1 東工大,[2 東工大,[3GNS Science,[4 兵庫県立大理,[5 神戸大理

Continuous EM-ACROSS Observation at Inferno Crater Lake, New Zealand

#Norihiro Kitaoka[1),Yasuo Ogawa[2),T. Grant Caldwell[3),Ishizu Keiichi[4),Takuto Minami[5),Alison Kirkby[3)
[1Tokyo Institute of Technology,[2Multi Resilience Research Center, Tokyo Institute of Technology,[3GNS Science, New Zealand,[4Graduate School of Science, University of Hyogo,[5Graduate School of Science, Kobe University

Monitoring resistivity structure is important for understanding the dynamics of volcanic hydrothermal systems because it is sensitive to fluid and vapor. The Inferno Crater Lake in the Taupo geothermal area, New Zealand, is suitable for monitoring hydrothermal system fluctuations because it has 38-day cycle changes with water level fluctuation of 9m and water temperature fluctuations from 35 ℃ to 75 ℃. We started continuous observations using the EM-ACROSS method, a precise artificial electromagnetic survey technique, on May 5, 2023. Here we report preliminary results.

The transmitter consists of two sets of 270 m long current dipoles located about 1 km south-southwest of Inferno Crater Lake in orthogonal directions. The transmitting waveform is a superposition of ten different frequency sine waves ranging from 0.9 Hz to 322.5 Hz with a repetition period of 20 seconds. We use slightly different frequency sets in the two dipoles, and we can separately extract signals from the two dipoles. For each dipole system, a 3 Vp-p signal is generated by a function generator. It is then amplified to 240 Vp-p by a power amplifier, with a current amplitude of 8 Ap-p. The transmit voltage and current are recorded at 1000 Hz on a logger via an output isolation monitor of the power amplifier, and the data is uploaded to a server every day. The transmitted signal fluctuation is stable within 0.01%, thanks to the GPS synchronization of the 10MHz signal.

We deployed ten ELOG-DUAL electric receivers within a radius of 150 m centered on Inferno Crater Lake and continuously recorded two orthogonal channels of electric fields at 2400 Hz sampling. We have processed the one-hour data by FFT, and obtained the signal and the noise amplitudes. Most of the S/N ratios are 100 and above. The amplitude variation in a day is about 3%. From the tentative analyses, we have found that an amplitude variation reaches 8% within 18 days, which is half of the period of the lake level fluctuation. In our presentation, we will show in detail the continuous observation data of the electric fields in comparison with the height and temperature fluctuations of the lake water.

火山熱水系のダイナミクスの理解のために、流体や蒸気に敏感な比抵抗構造をモニタリングすることは重要である。ニュージーランド国タウポ地熱地域にある Inferno Crater Lake は 38 日周期の変動があり、水位変動幅 9m、水温変動が 35 ℃から 75 ℃まで変動するため、熱水系変動のモニタリング観測に適している。われわれは 2023 年 5 月 5 日から精密人工電磁探査手法である EM-ACROSS 法を用いた連続観測を開始した。ここでは速報的な結果を報告する。

送信装置は Inferno Crater Lake から南南西に約 1km 離れた地点に設置された直交 2 方向の 270m 長の電流ダイポールである。送信波形は 0.9Hz から 322.5Hz までの 10 種類の周波数の正弦波を重ね合わせた繰り返し周期 20 秒の波である。ここで２つの系統でわずかに異なる周波数セットを用いることで、受信信号からダイポール別のテンソル信号を取り出すことが可能となっている。各系統について、3Vp-p の波をファンクションジェネレータで生成し、パワーアンプで 240Vp-p に増幅し、電流振幅は 8Ap-p である。送信電圧と送信電流はパワーアンプの出力絶縁モニタを介してロガーに 1000Hz で記録をし、1 日ごとにデータをサーバーにアップロードしている。送信信号の変動は 0.01% 程であり安定している。

受信点は Inferno Crater Lake を中心とする半径 150 ｍの範囲に 10 か所設置をした。NT システムデザイン社の ELOG-DUAL を用い、水平電場を 2400Hz で連続観測している。観測データに対し 1 時間ごとに高速フーリエ変換を行い、信号振幅と隣接するノイズの振幅を比較することで S/N 比が 100 倍ほどであることが分かり、受信信号とその誤差を取得することができている。受信信号の振幅の日変化は 3% 程度である。湖面変動の周期の半分に相当する 18 日間後のデータを比較すると 8 %の振幅の変動が観測されており、湖面変動に対応する比抵抗変動が有意に観測されている。講演では、電場観測データの連続観測データを詳細に示し、湖面水位変動、湖水水温変動との関連を議論する。

R003-10
D 会場 ：9/25　 PM2 （15:45-18:15）
16:30〜16:45

鬼界カルデラ火山海底下の三次元比抵抗構造解析

#小畑　拓実 [1), 荒木　将允 [1), 廣瀬　時 [1), 松野　哲男 [2), 南　拓人 [1), 大塚　宏徳 [2), 巽　好幸 [2), 杉岡　裕子 [1,2), 市原　寛 [3), 島　伸和 [1,2)
([1 神戸大・理・惑星,([2 神戸大海洋底探査センター,([3 名古屋大学地震火山研究センター,([4 名古屋大学地震火山研究センター

Imaging a 3-D resistivity structure under the Kikai submarine caldera volcano.

#Takumi Obata[1),Masamitsu Araki[1),Toki Hirose[1),Tetsuo Matsuno[2),Takuto Minami[1),Hironori Otsuka[2),Yoshiyuki Tatsumi[2),Hiroko Sugioka[1,2),Hiroshi Ichihara[3),Nobukazu Seama[1,2)
([1Department of Planetology, Graduate School of Science, Kobe University,([2Kobe Ocean Bottom Exploration Center, Kobe University,([3Earthquake and Volcano Research Center, Graduate School of Environmental Studies, Nagoya University,([4Earthquake and Volcano Research Center, Graduate School of Environmental Studies, Nagoya University

The Kikai caldera volcano, located in the southern part of Kagoshima Prefecture, is noted that it is fed by magma even after the latest giant caldera eruptions at 7.3ka (Tatsumi et al., 2018). To better understand the magma supply system leading to giant caldera eruptions, sub-seafloor structure is being estimated using geophysical data obtained on the seafloor and land around the Kikai caldera volcano.

We conducted ocean-bottom MT observations by Ocean Bottom ElectroMagnetometer (OBEM)s to image a sub-seafloor 3-D resistivity structure under the Kikai caldera volcano. Since the seafloor around the OBEM sites is very undulating, the bathymetric distortion of electromagnetic field is concerned. We therefore improved a 3-D MT inversion code, ModEM (Egbert and Kelbert, 2012; Kelbert et al., 2014), to handle 3-D resistivity models underlying the undulating bathymetry by applying the FS technique (Baba and Seama, 2002) to sea layers. We named this method ModEM+FS, and have confirmed the reliability of it (Obata et al., 2022, SGEPSS meeting). In our previous study, we estimate the resistivity structure under the Kikai caldera volcano by ModdEM+FS, but the fitting of calculated values to observed data is not necessarily good (Obata et al., 2023, JpGU meeting). The fitting between observations and calculations at 3 sites to the southern part of the caldera (RMS misfit >2) is worse especially than the total RMS misfit (1.57). In addition, there are unrealistic conductive patched areas (˜0.1 Ω-m) at the shallow part of the estimated model.

In this study, we aim to estimate more reliable model of sub-seafloor resistivity structure around Kikai caldera volcano. To achieve it, we investigate carefully the the influence of MT data on the inversion estimation of resistivity structure, regarding to site, period-range and element of the MT data used for the inversion. Based on the result of the investigation, we re-estimate MT impedances. For example, in the resistivity model Obata et al. (2023, JpGU meeting) showed, when we replace the resistivity for the unrealistic conductive shallow areas with realistic resistivity (1 Ω-m), RMS misfit at 4 sites increased to more than 1.5. Depending on these results, we consider the MT data that need to be re-estimated.

This presentation will propose an improved resistivity model by using new observational data at 8 sites in addition to the previous 18 sites data. This will increase the number of data sites in a distant area from the caldera, and is expected to provide a better estimation of the structure over a wider area than before. We will also report the result of analysis of the same MT data by another 3-D MT inversion code FEMTIC (Usui 2015; Usui et al. 2017) and compare the result of analysis by ModEM+FS.

鹿児島県南方に位置する鬼界カルデラ火山では、約 7300 年前の巨大カルデラ噴火以降もマグマが供給されている可能性が指摘されている (Tatsumi et al., 2018)。巨大カルデラ噴火をもたらすマグマ供給系への理解を深めることを目的として、鬼界カルデラ火山周辺の海底・陸上で得られた地球物理学的データによる、海底下の構造推定が進められている。

我々は、海底電位差磁力計 (OBEM) を用いた海底 MT 探査を行い、鬼界カルデラ火山海底下の三次元比抵抗構造推定を進めている。MT 観測点の周辺海域では海底地形の起伏が激しく、電磁場の歪みの影響が懸念される。そこで、三次元 MT インバージョンコード ModEM (Egbert and Kelbert, 2012; Kelbert et al., 2014) を、海水層に FS 法 (Baba and Seama, 2002) を適用して海底地形を表現したモデルが扱えるように改良した。これを ModEM+FS と名付け、コードの信頼性を確認した (小畑他 2022, SGEPSS)。これまで、本手法を用いた解析により鬼界カルデラ海底下の比抵抗構造の推定を進めてきたが、観測データと計算結果のフィッティングが不十分であった (小畑他 2023, JpGU)。特に、カルデラ南部 3 地点の RMS misfit は 2 以上であり、全体の RMS misfit(1.57) よりも高い数字を示した。また、浅部には非現実的に比抵抗値の低いパッチ状の領域 (˜0.1 Ω-m) が復元された。

このため、本研究では、より信頼性の高い鬼界カルデラ火山周辺の地下比抵抗構造の推定を行うことを目的とする。そのために、MT データの各地点・周期・成分が推定モデルへ与えている影響を精査し、MT インピーダンスの再推定を行う。例えば、小畑他 (2023, JpGU) において浅部に復元された低比抵抗領域を現実的な比抵抗値である 1 Ω-m に置き換えたところ、4 地点で RMS misfit が 1.5 以上増加した。これらの結果に基づいて、再推定が必要な MT インピーダンスを検討する。

本発表では、これまでに使用してきた 18 地点のデータに加え、新たに観測した 8 地点におけるデータを加えて解析

を行う予定である。これにより、カルデラ遠方のデータが増加し、より広域における構造の推定が期待できる。また、同じのデータを用いた別の三次元 MT インバージョンコード FEMTIC (Usui 2015; Usui et al. 2017) による解析も行い、ModEM+FS による解析結果と比較する予定である。

R003-11
D 会場 ：9/25 PM2 （15:45-18:15）
16:45～17:00

海底圧力データと海底磁場データのジョイントインバージョンによる 2007 年千島列島地震の津波波源推定

#柴原　澪 [1), 南　拓人 [2), 藤　浩明 [3)
([1 神戸大学大学院,([2 神戸大理,([3 京都大学・大学院・理学・地磁気センター

Tsunami source of the 2007 Kuril earthquake inferred by joint inversion of seafloor pressure and seafloor magnetic data

#Rei Shibahara[1)],Takuto Minami[2)],Hiroaki Toh[3)]
([1]Graduate School of Science, Kobe University,([2]Graduate School of Science, Kobe University,([3]Graduate School of Science, Kyoto University

Along the northern Kuril trench, a great outer-rise earthquake occurred on January 13, 2007, two months after an interplate earthquake on November 15, 2006. The model of slip distribution of the 2007 outer-rise earthquake estimated by the inversion using tide and seafloor pressure data has large slips on the middle part of the fault (Fujii & Satake, 2008). On the other hand, a model in which slips are present at the southern and northern ends of the fault, with a local concentration of slips, especially at the southern end has been estimated by inversion using seafloor magnetic field data (Kawashima & Toh, 2016). In this study, we performed joint inversion using seafloor pressure data at two DART sites (21413 and 52405) near Japan and three-component magnetic data obtained at a seafloor site (NWP) in the northwest Pacific to obtain slip distribution explaining both data types simultaneously. Joint inversion using Green's functions calculated with tsunami simulation based on linear dispersive wave theory (Baba et al. 2017) and time-domain electromagnetic field simulation (Minami et al. 2017) resulted in a model with large slips in the southern part of the fault. In the inversion, we set 20 min time window at the arrival time of the first wave at each station and calculated the residual terms of the wave height and the three magnetic field components. The observed amplitude of the tsunami-induced magnetic fields was about 1nT, and the amplitude of the observed tsunami wave heights at two DART stations (21413 and 52405) was about 0.02m and about 0,01m, respectively. The synthetic wave from the estimated model reproduces the first wave of the observation data and the RMS of the wave height and magnetic field are 0.0076m and 0.314nT, respectively. In comparison with previous studies, Fujii & Satake, (2008) showed the different locations of subfaults where slips exist, and the local concentration of slips in Kawashima & Toh, (2016) was not found in this study. We report the details of the inversion method and the slip distribution when more seafloor pressure data are used.

千島海溝沿いでは、2006 年 11 月 15 日にプレート境界型の地震が、さらに、2 ヶ月後の 2007 年 1 月 13 日にアウターライズ地震が発生した。2007 年のアウターライズ地震の津波を発生させた断層のすべり分布については、潮位データ及び海底圧力データを用いたインバージョンによって、断層の中央部分に大きなすべりが存在するモデルが推定されている (Fujii & Satake, 2008)。また、海底磁場データを用いたインバージョンでは断層の南北端にすべりが存在し、特に南端ですべりが局所的に集中するモデルが得られている (Kawashima & Toh, 2016)。本研究では、日本近海の DART 2 地点 (21413、52405) での海底圧力データ、及び、北西太平洋海盆の海底電磁場観測点 (NWP) における海底磁場３成分データを併用したジョイントインバージョンによって、2 種類の観測データを同時に説明するすべり分布を推定した。線形分散波理論に基づく津波計算 (Baba et al. 2017) 及び、時間領域の電磁場シミュレーション (Minami et al. 2017) によって作成したグリーン関数を用いたインバージョンの結果、断層の南部分に大きなすべりが存在するモデルが得られた。インバージョンでは、各観測点の津波第一波到来時刻を中心に 20 分の時間窓を設定し、波高及び磁場三成分の残差項を計算した。津波第一波に起因する NWP の観測磁場振幅は約 1nT, DART2 点での観測波高の振幅は約 0.02m と約 0.01m であったが、推定したすべり分布を用いた合成波は観測データの第一波をよく再現しており、波高データの RMS は 7.57 × 10^(-3) m、磁場の RMS は 0.314nT であった。先行研究との比較では、Fujii & Satake, (2008) とはすべりが存在する小断層の位置の違いが見られ、Kawashima & Toh, (2016) でのすべりの局所的な集中は本研究では見られなかった。本発表では、採用したインバージョン手法の詳細と得られたすべり分布、さらに使用する海底圧力データを増やした場合のすべり分布について、報告する。

R003-P01
ポスター２：9/25　AM1/AM2 （9:00-12:30）

高相関な密度-磁化モデル取得のための group lasso を用いた磁気・重力ジョイントインバージョン

#宇津木　充 1)
(1 京大・理・火山研究センター

Magnetic and gravity joint inversion for obtaining highly correlated density-magnetization models using group lasso reguralization

#Mitsuru Utsugi1)
(1 Aso Volcanological Laboratory, Kyoto University

The magnetic and gravity surveys are powerful methods for obtaining information of the subsurface structure, and both are highly compatible with each other based on potential theory. Thus, many studies have been focued on the gravity and magnetic joint inversion.

In such studies, it is often apply the constraint that the density structure obtained from the gravity data to be correlated with the magnetization structure obtained from the magnetic field data, and recent studies used the methods such as cross gradient, fuzzy c-means method, and correspondence maps etc. for this purpose. In these analyses, the subsurface is divided into small block cells, and the density and magnetization of each cell are calculated.

In out study, we attempted to introduce a regularization method called "group lasso" in the joint inversion of magnetic and gravity data. The group lasso is a method in which model elements can be divided into several groups (clusters), and the elements belonging to each group are constrained to take zero or non-zero values. Making groups (paiers) of density and magnetization of each grid cells, we attempted to apply this group lasso method to the gravity and magnetic joint inversion. This means that where density or magnetization takes a non-zero value, the other will also be non-zero, and conversely, if one is zero, the other is also likely to be zero. As a result, derived density and magnetization structures are expected to have similar shape with high correlation.

The advantages of applying group lasso method are 1) ease of implementation, and 2) the ability to impose sparsity in addition to group effects on the model at the same time. In particular, the optimization of the nonlinear group lasso penalty can be obtained analytically using the proximal gradient method, and thus, we can implement it with a very simple code. Further, since the group lasso penalty is a vector version of the L1 norm penalty and it is also a sort of the sparsity promoting penalty, it is expected that the resultant model have sparseness feature.

In this presentation, we will show the details of the calculation method as well as some examples of its application to the synthetic tests and the real data study.

磁場、重力探査は地下構造についての情報を得るための有力な手法であり、どちらもポテンシャル理論に基づき親和性が高い事から、構造解析においてはこれらのデータを同時に使用したジョイントインバージョンが古くから研究されてきた。その際、重力データから得られる密度構造と、磁場データから得られる磁化構造が相関を持つような拘束を与える事が多く、そのために例えば cross gradient、fuzzy c-means、correspondence maps などを用いた解析方法が提案されている。ここで、これらの解析においては地下を小ブロックに分割し各々のブロックの密度、磁化を求めるという方法が一般的に用いられている。

本研究では、磁重力ジョイントインバージョンにおいて group lasso と呼ばれる正則化方法の導入を試みた。group lasso とは、モデル要素をいくつかのグループ（クラスター）に分割できる場合に、そのグループに属す要素をまとめてゼロ、もしくは非ゼロの値を取るよう拘束を与えられるものである。この方法を用い各々の地下ブロックの密度と磁化をグループにして group lasso を適用する事を試みた。これにより、密度、磁化の一方が非ゼロの値を取るブロックでは他方も非ゼロとなり、逆に一方がゼロになれば他方もゼロになりやすくなる。その結果、得られる密度、磁化構造は形の似通った、相関の高い構造となる事が期待される。この方法を用いる利点としては、1. 実装が容易である、ことに加え 2. グループ効果に加えスパース性をモデルに課すことが出来る、という事が挙げられる。特に 1. については、本来非線形な group lasso のペナルティの最適化解が近接勾配法に依り解析的に求められるので非常に簡単なコードで実装できる。2. については、group lasso ペナルティは L1 ノルムペナルティのベクトル版でありスパース正則化法の一種なので、その導入により先行研究で指摘された磁場・重力スパースインバージョンの恩恵をそのまま享受できることが期待される。本発表では計算方法の詳細に加え、シンセティックテスト及び実データに適用した例について紹介する。

R003-P02
ポスター２：9/25　AM1/AM2（9:00-12:30）

エチオピア・アファール凹地における徒歩磁場観測データの解析

#伊藤　良介 [1], 吉村　令慧 [2], 石川　尚人 [3],Tesfaye KIDANE[4], 加々島　慎一 [5], 望月　伸竜 [6], 宇津木　充 [7]
([1] 京都大学理学研究科,([2] 京都大学防災研究所,([3] 富山大学都市デザイン学部,([4] アメリカ合衆国 Wayne State 大学,([5] 山形大学理学部,([6] 熊本大学大学院先端科学研究部（理）,([7] 京都大学地球熱学研究施設附属火山研究センター,([8] 熊本大学

The analysis of walking magnetic field observation data in the Afar Depression, Ethiopia

#Ryosuke Ito[1],Ryokei Yoshimura[2],Naoto Ishikawa[3],KIDANE Tesfaye[4],Shin-ichi Kagashima[5],Nobutatsu Mochizuki[6],Mitsuru Utsugi[7]
([1]Kyoto University,([2]Disaster Prevention Research Institute, Kyoto University,([3]Faculty of Sustainable system, University of Toyama,([4]Department of Environmental Science and Geology, Wayne State University, Detroit, MI-48202, USA,([5]Faculty of Science, Yamagata University,([6]Faculty of Advanced Science and Technology, Kumamoto University,([7]Aso Volcanological Laboratory, Graduate school of Science, Kyoto University,([8]Department of Earth and Environmental Science, Faculty of Advanced Science and Technology, Kumamoto University

The Afar depression in Ethiopia is located at the triple junction of the divergent plate boundaries of the Nubian, Arabian and Somali plates. This area is considered to be at the beginning stages of an ocean floor spreading event that has progressed from continental rifting (Ishikawa, 2021). In particular, in the area around Dabbahu volcano (Dabbahu Rift), there was active seismic activity and normal fault formation from 2005 to 2010, and lava eruptions were observed in some areas. Analysis of GPS and seismic data has estimated that there were repeated localized vein intrusions 10-60 km long and 1-3 m wide, with total vein intrusions ranging from 8 m wide, 60 km long and 2-10 km deep (e.g. Ebinger et al., 2010). Thus, the area must be an excellent field for exploring the subsurface structure of the ocean floor spreading axis area and the formation process of magnetic anomalies.

We carried out the walking magnetic field observation in the Afar depression in 2016. The observation was conducted over four days on a measuring line with a height difference of approximately 90 m and a length of approximately 56.8 km (68.5 km alongside). In this study, the sparse magnetic inversion analysis (Utsugi, 2019) was applied to the acquired data. The results suggest the presence of positively and negatively magnetized regions representing past igneous activity at depth. By extracting signals derived from shallow structures and comparing them with the results of rock magnetic studies, we attempted to elucidate the formation process of the stripe pattern of magnetic anomalies associated with the spreading of the ocean floor.

エチオピア・アファール凹地は、ヌービアプレート・アラビアプレート・ソマリアプレートの拡大プレート三重会合点に位置し、大陸リフティングから進行した海洋底拡大現象の開始時期の段階にあると考えられている（石川, 2021）。特に、Dabbahu 火山周辺域では 2005 年から 2010 年にかけて活発な地震活動と正断層系の形成が観測され、幅 8m、長さ 60km、深さ 2〜10km の岩脈貫入が起きたと推定されている（e.g. Ebinger et al., 2010）。すなわち、この地域は海洋底拡大軸域の地下構造や縞状磁気異常の形成過程を探るのに理想的なフィールドである。

2016 年、アファール凹地において徒歩磁場観測が実施された。観測は高低差約 90m・長さ約 56.8km（沿面長約 68.5km）に及ぶ測線で 4 日間にわたって行われた。本研究では、取得されたデータにスパース性を考慮した磁気インバージョン解析（Utsugi, 2019）を適用した。その結果、深部に過去の火成活動を示唆する正負の磁化構造の存在が推定された。また、浅部の構造に由来する信号を抽出し、岩石磁気研究の結果と比較を行うことで、海洋底拡大にともなう磁気異常の縞模様の形成過程の解明を試みた。

#ディバ　ディエノ [1), 上嶋　誠 [1), 市來　雅啓 [2), 坂中　伸也 [3), 田村　慎 [4),Yuan Yiren[1,5),Gresse Marceau[1,6), 山谷　祐介 [6),SONG　Han[1,7), 臼井　嘉哉 [1)
(1 東大・震研,(2 東北大院理,(3 秋田大・国際資源,(4 道総研エネ環地研,(5IGP, CEA,(6 産総研,(7 同済·海地国重室

Constrained inversion of MT data with seismic velocity model in the southern part of NE Japan

#Dieno Diba[1),Makoto Uyeshima[1),Masahiro Ichiki[2),Shinya Sakanaka[3),Makoto Tamura[4),Yiren Yuan[1,5),Marceau Gresse[1,6),Yusuke Yamaya[6),Han SONG[1,7),Yoshiya Usui[1)
(1Earthquake Research Institute, the University of Tokyo,(2Graduate School of Science, Tohoku University,(3Graduate school of International Resource Sciences, Akita University,(4Hokkaido Research Organization, Research Institute of Energy, Environment and Geology,(5Institute of Geophysics, China Earthquake Administration,(6National Institution of Advanced Industrial Science and Technology,(7State Key Laboratory of Marine Geology, Tongji University, Shanghai, China

The integration of one or more independently derived physical Earth models in the magnetotelluric (MT) inversion can result in a narrower solution space of resistivity models, leading to higher confidence for geological interpretations (e.g., Kalscheuer et al., 2015; Franz et al., 2021). It is called constrained or cooperative MT inversion. The resulting resistivity structure is required to explain the observation and satisfy a certain relationship to the constraining model. In this study, we apply the idea of constrained inversion to study the subsurface structure beneath the southern part of NE Japan, especially to reveal the deep fluid distribution associated with active volcanoes and seismic activities. Previously, a resistivity structure was obtained from an MT-only inversion (Diba et al., 2023). Here, we use the same MT datasets, but the inversion is constrained using a pre-existing seismic velocity structure by Matsubara et al. (2022). To couple the inversion and the fixed velocity model, we used a structural cross-gradient coupling, which enforces a structural similarity between the resistivity and velocity model (e.g., Gallardo and Meju, 2003). Cross-gradient is a widely accepted coupling strategy, especially suitable when defining a direct relationship between resistivity and velocity is difficult. The objective function of the FEMTIC inversion code (Usui, 2015) was modified to include the cross-gradient coupling term in addition to the data misfit and regularization terms. The resulting models and evolution of objective function terms will be discussed in the presentation, as well as our approach for obtaining the optimum weights in the objective function.

R003-P04
ポスター２：9/25　AM1/AM2（9:00-12:30）

#臼井　嘉哉[1), 上嶋　誠[1), 坂中　伸也[2), 橋本　匡[1), 金子　柊[3), 市來　雅啓[4), 海田　俊輝[4), 山谷　祐介[5), 木原　尚平[6), 小山　崇夫[1), 宮川　幸治[1), 平瀬　敬司[6), 星野　剛右[6), 冨岡　優貴[6), 井手　健斗[6), 清水　連太郎[6), 寺井　周[6), 吉江　雄太[6), 小川　康雄[7), 北岡　紀広[7), 増田　正孝[1), 秋山　峻寛[1), ディバ　ディエノ[1), 一松　駿斗[8), 村北　貴郁[6), 中谷内　奎[6), 渡部　熙[1), 崎山　律[2)
[(1] 東京大学地震研究所,[(2] 秋田大学工学資源学部,[(3] 千葉大学大学院融合理工学府,[(4] 東北大学大学院理学研究科,[(5] 産業技術総合研究所 再生可能エネルギー研究センター,[(6] 独立行政法人エネルギー・金属鉱物資源機構,[(7] 東京工業大学科学技術創成研究院,[(8] 富山大学大学院理工学教育部

Characteristic features of the magnetotelluric response functions in the northern Kanto region

#Yoshiya Usui[1)],Makoto Uyeshima[1)],Shinya Sakanaka[2)],Tasuku Hashimoto[1)],Shu Kaneko[3)],Masahiro Ichiki[4)],Toshiki Kaida[4)],Yusuke Yamaya[5)],Shohei Kihara[6)],Takao Koyama[1)],Koji Miyakawa[1)],Keiji Hirase[6)],Gosuke Hoshino[6)],Yuki Tomioka[6)],Kento Ide[6)],Rentaro Shimizu[6)],Amane Terai[6)],Yuta Yoshie[6)],Yasuo Ogawa[7)],Norihiro Kitaoka[7)],Masataka Masuda[1)],Takahiro Akiyama[1)],Dieno Diba[1)],Hayato Hitotsumatsu[8)],Takafumi Murakita[6)],Kei Nakayauchi[6)],Akira Watanabe[1)],Ritsu Sakiyama[2)]
[(1]Earthquake Research Institute,The University of Tokyo,[(2]Graduate school of International Resource Sciences, Akita University,[(3]Graduate school of Science and Engineering, Chiba University,[(4]Graduate School of Science, Tohoku University,[(5]National Institute of Advanced Industrial Science and Technology,[(6]Japan Organization for Metals and Energy Security,[(7]Institute of Innovative Research, Tokyo Institute of Technology,[(8]Department of Earth Science, Toyama University

There are several quaternary volcanos in the northern Kanto region (e.g., Nasu, Takahara, and Hiuchigatake). In the vicinity of some of the volcanoes, deep low-frequency earthquakes occur, implying the transfer of melt or aqueous fluid. Geochemical studies based on isotopic ratios of volcanic rocks have suggested that the aseismic Philippine Sea slab extends beyond the northern Kanto region and perturbs mantle flow, enhancing the flux of the slab-derived fluid to the northern margin of the Kanto region. In order to elucidate the transport of the slab-derived fluid and the magma supply system, it is important to reveal the subsurface fluid distribution by conducting an electromagnetic induction survey that delineates the subsurface electrical resistivity structure. However, the regional electrical resistivity structure in the northern Kanto region has not yet been investigated. Thus, the authors performed magnetotelluric surveys around the northern margin of the Kanto region in 2021 and 2022. From the measured time-series data, the authors estimated the impedance tensor and the vertical magnetic transfer function using a robust MT data processing method. The estimated response functions show characteristic features appearing to be associated with the volcanos around the survey area. Around Nasu volcano, the phase tensor ellipses are flattened, and Φ_{max} is significantly higher than 45 (deg.) at periods of longer than several hundred seconds. Because the major axes of the phase tensor ellipses tend to be aligned perpendicular to the island arc, this tendency might indicate a conductor along the island arc. In addition, the Parkinson vectors point toward the volcanoes, which also implies conductors beneath the volcanoes. In this presentation, the authors show the characteristic features of the obtained MT response functions and give some interpretations of them.

R003-P05
ポスター２：9/25　AM1/AM2（9:00-12:30）

ニュージーランド北島の火山・非火山地域における長周期 MT 法観測

#畑　真紀 [1), 上嶋　誠 [2),Caldwell　T. Grant[3), 臼井　嘉哉 [2), 小川　康雄 [4),Heise　Wiebke[3),Caldwell Alex[3),Bennie　Stewart L.[3), 吉村　令慧 [1)
[(1] 京大・防災研,[(2] 東大・地震研,[(3]GNS Science,[(4] 東工大

Long-period MT surveys at volcanic and non-volcanic regions in North Island of New Zealand

#Maki Hata[1)],Makoto Uyeshima[2)],T. Grant Caldwell[3)],Yoshiya Usui[2)],Yasuo Ogawa[4)],Wiebke Heise[3)],Alex Caldwell[3)],Stewart L. Bennie[3)],Ryokei Yoshimura[1)]
[(1]Disaster Prevention Research Institute, Kyoto University,[(2]Earthquake Research Institute, the University of Tokyo,[(3]GNS Science,[(4]Multi Resilience Research Center, Tokyo Institute of Technology

The northern part of the North Island of New Zealand is characterized by subduction-related volcanism in the NNW-oriented Coromandel Volcanic Zone during the Miocene-Pliocene and the NE-oriented active Taupo Volcanic Zone (TVZ) during Pleistocene-Recent. The subduction of Pacific Plate and Hikurangi Plateau, with the velocity of subduction ranging from 6 cm/year in the north to 2.5 cm/year in the south [e.g., Wallace et al. 2004], involves the formation of the volcanic island of the North Island. The central part of TVZ discharges ~ 4.2 GW of extraordinary heat flux originated in recent silicic volcanism [e.g., Bibby et al., 1995; Wilson et al., 1995]. Seismic and electromagnetic research have been reported the crustal and upper mantle heterogeneity with magma/melt reservoirs beneath the TVZ [e.g., Stratford and Stern, 2006; Heise et al., 2007]. On the other hand, it is interesting that no volcanic structures are distributed in the southern part of the North Island. Moreover, slow and ordinary earthquakes highly occur in the North Island. Geodetic studies present undocumented deep (25 – 45 km depth), moderate-duration (2 – 3months) slow slip events (SSEs) directly downdip of known shallow (<15km depth), short-term (2 – 3weeks) SSEs at the fore arc of the Hikurangi margin [e.g., Wallace&Eberhart-Phillips, 2013]. At the Gisborne and Manawatu regions in the fore arc, tectonic tremors have been detected. In the subduction zones, it is considered that the fluid/magmatic system in the mantle wedge play a large role in the volcanic and seismic activities. However, the structure of the underlying fluid/magmatic system beneath the North Island is unclear. So thus, we conducted long-period MT surveys in a target region, which covers the southernmost part of the TVZ and the non-volcanic region, in order to reveal the structure of the underlying fluid/magmatic system in the subduction dynamics. In this presentation, we mainly show details of the long-period MT surveys and preliminary analysis results of obtained long-period MT data.

R003-P06
ポスター２：9/25　AM1/AM2（9:00-12:30）

東北地方の虚部インダクションベクトルによる東北北部・北海道西部の最上部マントル比抵抗異常フォワードモデリング

#市來　雅啓 [1), 海田　俊輝 [1), 小川　康雄 [2), 臼井　嘉哉 [3)
(1 東北大院理,(2 東工大,(3 東大地震研

A forward modeling approach for resistivity model beneath Tohoku and Hokkaido using the quadrature-phase induction vectors

#Masahiro Ichiki[1)],Toshiki Kaida[1)],Yasuo Ogawa[2)],Yoshiya Usui[3)]
(1Graduate School of Science, Tohoku University,(2Multi Resilience Research Center, Tokyo Institute of Technology,(3Earthquake Research Institute,The University of Tokyo

1. Introduction

The quadrature-phase induction vectors (QIVs) of the northern Tohoku in the periods of 5000 to 10,000 s point northward. This suggests the possibility of a high-conductivity anomaly in the uppermost mantle beneath Tsugaru strait to western Hokkaido. To investigate this possibility, we confirmed the basic nature of QIV attitude in which QIVs pointed towards a vertical boundary of a resistivity structure and that neither the coastline nor the oceanic effects could explain the QIV of the northern Tohoku in the periods of 5000 to 10,000 s (Ichiki et al. 2021, 2022 SGEPSS Fall Meeting). These results support the possibility of a high-conductivity anomaly in the uppermost mantle beneath western Hokkaido to Aomori prefecture. In this study, we consider whether the resistivity model candidate for the uppermost mantle beneath Oshima peninsula to Aomori prefecture proposed by the precious study can explain QIV by using a forward modeling approach.

2. Model and result

The finite element method code with tetrahedral elements (Usui, 2015 GJI) was used for forward modeling. The model origin was set at N40 degree, E 141 degree within Mutsu Bay. The model within the area of 100 km distance from the origin was discretized with tetrahedral elements whose edge lengths were less than 5 km. In the discretization, we referred to GSHHS Fine (Bessel & Smith, 1996 JGR) for the coastline and SRTM30+ (Becker et al., 2009 Marine Geodesy) for the ocean bathymetry.

Nishida (1982 JGG) proposed a resistivity model including resistivity heterogeneity in the uppermost mantle beneath Oshima peninsula to Aomori prefecture using the in-phase induction vectors in the periods of 10 to 120 minutes observed in Hokkaido and Aomori prefectures. The modeling method was thin-sheet modeling. The model consists of the crust and mantle. The Moho discontinuity is assigned to the depth of 30 km, and the rectangular conductive heterogeneity elongated in the NS direction in the uppermost mantle beneath Oshima peninsula to Aomori prefecture is embedded in the depths of 30 to 70 km. Referring to this model, we made a test model which had a horizontal boundary at a depth of 70 km and had the convex of the lower medium within the upper medium. The convex top is at a depth of 30 km. The resistivity of the lower and upper media are 10 and 1000 Ω m, respectively.

The QIVs in northern Tohoku in the periods of 5000-10000 s calculated from the test model pointed southwards, which was an opposite result from the observation. When we replaced the resistivity values of the lower and upper media with each other, the calculated QIVs partly pointed northwards, which agreed with the observed QIVs attitude. The in-phase induction vectors calculated from the latter model did not show a significant change from those calculated from the former model because the in-phase induction vectors were affected by oceanic and coastline effects.

3. Conclusion and future study

This study suggests a high-resistivity anomaly in the uppermost mantle beneath Oshima peninsula to Aomori prefecture. We should estimate the influence of subducting Pacific slab on the QIVs in the next study.

1.　はじめに

東北地方北部の周期 5000～10000 秒の虚部のインダクションベクトル (Quadrature phase Induction Vector; QIV) は北向きを示している。この傾向は津軽海峡から北海道西部の上部マントルに高伝導の異常体がある可能性を示唆する。我々は QIV が比抵抗構造の鉛直境界の方向を指すこと、海水とマントルの低比抵抗体からなるモデルでは表皮深度に応じたマントル低比抵抗体を指すこと、海岸線効果や海底地形効果では東北地方北部の周期 5000～10000 秒の QIV を説明できないことを報告し (市來　他, 2021, 2022 SGEPSS 秋季大会)、その可能性を支持してきた。本報告では、これまで提案された渡島半島から青森にかけてのマントル最上部の比抵抗異常モデルが QIV を説明できるかフォワードモデリングで考察した。

2.　モデルと結果

フォワードモデリングには 4 面体要素 3 次元有限要素法コード (Usui, 2015 GJI) を用いた。モデル中心は陸奥湾内の北

緯 40 度、東経 141 度の海水面とし、空中を除いて中心より 100 km の範囲は辺要素が 5 km 以内になるように要素を離散化した。海岸線データは GSHHS Fine(Bessel & Smith, 1996 JGR)、海底地形は SRTM30+(Becker et al., 2009 Marine Geodesy) を用いて要素の離散化を行った。

Nishida (1982 JGG) は北海道と青森の観測点で観測された周期 10〜120 分の実部のインダクションベクトルを用いて薄層近似モデリングコードでマントル最上部に比抵抗構造不均質があるモデルを提案した。そのモデルはモホ面深さ 30 km、地殻が 1000 Ω m、マントルを 100 Ω m として、渡島半島から青森にかけてマントル最上部（深さ 30〜70 km）に 10 Ω m の南北に長い直方体の不均質を持つモデルである。本研究はこのモデルを参考に、水平境界面の深さを 70 km として、深さ 0〜70 km を 1000 Ω m、70 km 以深を 10 Ωm、渡島半島から青森直下の深さ 30〜70 km に直方体の 10 Ω m の高伝導凸構造を持つモデルに対して東北北部の QIV を計算した。

その結果、注目している周期 5000〜10000 秒の QIV は南向きを示した。そこで逆に深さ 0〜70 km を 100 Ω m、70 km 以深を 1000 Ω m、渡島半島から青森直下の深さ 30〜70 km に直方体の 1000 Ω m の高抵抗凸構造を持つモデルに対して東北北部の QIV を計算したところ、部分的に北向きの QIV を実現できた。実部のインダクションベクトルは海洋効果や海岸線効果の影響を受けているため大きなパターンの変化は見られない。

3.　まとめと今後の課題

インダクションベクトルのパターンを基にすると、虚部のインダクションベクトルの振る舞いは、渡島半島から青森までの最上部マントルに寧ろ高比抵抗の異常体があることを示唆した。今後の課題は沈み込むスラブの影響の考察が必要である。

R003-P07
ポスター２：9/25　AM1/AM2 （9:00-12:30）

岩石比抵抗の解釈に向けた既存坑井データを用いた分析

#井上　智裕[1), 橋本　武志[2)
(1 九州大学・理・地震火山センター,(2 北海道大学・理・地震火山センター

Analysis of well data for the interpretation of rock resistivity

#Tomohiro Inoue[1),Takeshi Hashimoto[2)
(1Institute of Seismology and Volcanology, Faculty of Science, Kyushu University,(2Institute of Seismology and Volcanology, Faculty of Science, Hokkaido University

Recent studies worldwide have revealed three-dimensional resistivity structures beneath active volcanoes. Many of them have reported low resistivity layers of 1-10 Ω m in the shallow part of the volcanoes. Such shallow conductive layers are sometimes interpreted as porous layers filled with hydrothermal water. However, they are also often interpreted as impermeable zones rich in highly conductive clay minerals. It is essential to distinguish between aquifers and impermeable layers when considering the hydraulic structure of a volcanic body in relation to evaluating the potential of phreatic eruptions. Meanwhile, they are indistinguishable in principle based on bulk resistivity information of rocks alone. Therefore, we have read and compiled the well data from the published reports by NEDO (New Energy and Industrial Technology Development Organization) for potential geothermal areas where the subsurface conditions are similar to volcanic areas. However, the quantitative relationship between various physical properties of rock samples and rock resistivity is not yet clear. In this study, the relationship between rock resistivity and other physical properties was examined using the well data that we compiled.

Our study covered 23 areas from a series of NEDO's survey that contained physical logging and core property tests (long-normal electrical logging, temperature logging, density, effective porosity, magnetic susceptibility, seismic velocity, thermal conductivity, and mineral contents). We referred to the resistivity values from the long-normal electrical logging data. The NEDO's survey reports provided the content of mineral species for core samples in five-level qualitative evaluation. In this study, we quantified the evaluation and calculated the weighted sum based on the mineral species to produce the "conductive clay index (CCI)". The weights are 80 for smectite, 13 for sericite, 6 for kaolin minerals, 6 for chlorite, and 0 for other clay minerals, referring to the cation exchange capacity (CEC) of minerals.

We used 4946 samples that had complete sets of physical property test data in this study. First, we examined the relationship between rock resistivity and each property. We found a negative correlation between effective porosity and resistivity. On the other hand, positive correlations were found between density, seismic velocity, and thermal conductivity and rock resistivity. Samples with higher effective porosity tended to have higher CCI. Samples with relatively high density, seismic velocity, and thermal conductivity tended to have low CCI. These results suggest that rocks rich in porosity are more susceptible to hydrothermal alteration due to easy circulation of hydrothermal fluids, while dense rocks are less susceptible to alteration. While there was a correlation between resistivity and other physical properties, there was no clear relationship between resistivity and magnetic susceptibility.

Next, no clear correlation was observed between the amount of chlorite and sericite and the resistivity of each mineral. Conversely, increasing the quantity of montmorillonite and kaolin minerals resulted in decreased resistivity in the samples. Samples with higher montmorillonite content exhibited relatively high porosity, whereas samples with higher kaolin mineral content displayed low porosity. This suggests that kaolin-rich rocks may exhibit cap rock-like properties compared to montmorillonite-rich rocks.

We performed the principal component analysis to determine the degree of physical properties that contribute to rock resistivity. In this study, we classified samples based on rock resistivity, and performed the principal component analysis considering the dimensions of temperature, density, effective porosity, magnetic susceptibility, elastic wave velocity, thermal conductivity, and various mineral contents. First, the cumulative contribution of the first through third principal components is about 80%, suggesting that these three principal components explain about 80% of the variation in the total data. The high total contribution from the first to the third principal components suggests that these principal components related to the rock resistivity. Scatter plots with the first, second and third principal components showed clusters with low resistivity. These clusters indicates that each principal component may be involved in the classification of the rock resistivity.

In this study, we conducted the analysis of rock resistivity and various physical properties using the well data. In the future, we aim to investigate the physical properties and principal components of the clusters that appeared by using statistical methods.

Acknowledgments: This research was supported by the Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT) under the subject B in Integrated Program for Next Generation Volcano Research and Human Resource Development. This research used NEDO's Geothermal Development Promotion Study Report, which is available on the JOGMEC website (https://geothermal.jogmec.go.jp/report/nedo/).

近年，Magnetotelluric 法（MT 法）による比抵抗構造探査によって，活動的火山の地下浅部にはしばしば 1-10 Ω m の低比抵抗な層があることがわかってきた．火山帯や地熱地帯における浅部低比抵抗層は，地下水で満たされた帯水層と解釈されるが，導電性粘土鉱物を豊富に含む難透水層（粘土キャップ）と解釈するケースもある．火山活動（e.g. 水蒸気噴火）との関連で火山体の水理構造を考える上では，両者を区別することが重要であるが，岩石のバルク比抵抗の情報のみからでは，それは原理的に困難である．そこで，これまで我々は，NEDO（新エネルギー・産業技術総合開発機構）による地熱開発促進調査報告書から，火山と地下の環境が近い地熱地帯の坑井データの読み取りと整理を行ってきた．しかし，岩石試料の様々な物性値と岩石比抵抗の定量的な関係はまだ明らかでない．本研究では，これまで読み取ってきた坑井データを使用して，岩石比抵抗とその他の物性値の関係を検討した．

本研究は，NEDO による物性試験結果（ロングノルマル電気検層，温度検層，密度，有効空隙率，帯磁率，弾性波速度，熱伝導率，粘土鉱物の種類と量）が全て揃っている 23 地域を対象にした．NEDO 調査報告書では，鉱物量として X 線分析による 5 段階評価（多量=4，中量=3，少量=2，微量=1，無=0）が記載されている．その値に導電性が高い鉱物種ごとの重みをかけた和を，その岩石試料における「導電粘土鉱物指標」とした．ここでは，重みとして，鉱物の陽イオン交換容量（CEC）を参考に，スメクタイトを 80，セリサイトを 13，カオリン鉱物を 6，緑泥石を 6，その他の粘土鉱物を 0 とした．

本研究では，物性試験データが全て揃っている試料のみを抽出し，合計 4946 サンプルを使用した．まず，岩石比抵抗と各物性値の関係を調べたところ，有効空隙率と比抵抗の間には負の相関が見られた．一方で，密度，弾性波速度，熱伝導率の各物性値と岩石比抵抗とは正の相関が見られた．また，有効空隙率が高い試料は，導電性粘土鉱物指標が高い傾向であった．密度，弾性波速度，熱伝導率が比較的高い試料は，導電性粘土鉱物が低い傾向であった．これらのことは，空隙に富む岩石では熱水が循環しやすく熱水変質が起こりやすくなり，反対に緻密な岩石は変質度合いが低いことが考えられる．以上のように比抵抗とその他の物性に相関があった一方で，比抵抗と帯磁率の間には，明瞭な関係は読み取れなかった．

次に，個々の鉱物量について注目すると，緑泥石・セリサイトの量と比抵抗の間には明瞭な相関は現れなかった．一方で，モンモリロナイトやカオリン鉱物の量が多いほど低比抵抗を示す試料が多かった．モンモリロナイト量が高い試料は高空隙率を示す試料が多く，カオリン鉱物量が高い試料は低空隙率を示す試料が多い傾向であった．このことから，モンモリロナイトに富む岩石に比べて，カオリン鉱物に富む岩石が粘土キャップのような性質を示す可能性がある．

岩石比抵抗に寄与する物性の程度を把握するために，主成分分析を行った．本研究では，岩石比抵抗値に基づいて試料を分類し，温度，密度，有効空隙率，帯磁率，弾性波速度，熱伝導率，各種鉱物量の次元を考慮して主成分分析を行った．まず，第 1 主成分から第 3 主成分までの累積寄与率は約 80% であり，これらの 3 つの主成分が全データの約 80% の変動を説明している．第 1 主成分から第 3 主成分までの寄与率の合計が高いことから，これらの主成分が岩石比抵抗と関係があると考えられる．また，第 1 主成分，第 2 主成分，第 3 主成分で散布図を作成したところ，低比抵抗を示す試料のクラスタが見られた．このようなクラスタが現れたことから，それぞれの主成分が岩石の比抵抗の分類に関与している可能性を示す．

本研究では，既存坑井データに見られる岩石比抵抗と他物性間の傾向を明らかにした．今後，統計的手法によって現れたクラスタの物性や主成分の意味を検討し，そのクラスタの定量化及び評価を目指す．

謝辞：本研究は，文部科学省「次世代火山研究・人材育成総合プログラム」課題 B の支援を受けた．また，本研究は NEDO の地熱開発推進調査報告書を利用した．これらの報告書は JOGMEC のウェブサイト (https://geothermal.jogmec.go.jp/report/nedo/) で公開されているものを使用した．

R003-P08
ポスター２：9/25　AM1/AM2（9:00-12:30）

機械学習を用いた津波誘導磁場検出手法の開発と実観測データによる検証

#美田　千璃 [1), 南　拓人 [1), 杉岡　裕子 [1), 藤　浩明 [2)
(1 神戸大学・大学院・理学,(2 京都大学・大学院・理学,(3 京都大学・大学院・理学・地磁気センター

Development of machine learning model for detection of tsunami magnetic signals in seafloor magnetic data

#Chiaki Mita[1),Takuto Minami[1),Hiroko Sugioka[1),Hiroaki Toh[2)
(1Graduate School of Science, Kobe University,(2Graduate School of Science, Kyoto University,(3Data Analysis Centre for Geomagnetism and Space Magnetism, Graduate School of Science, Kyoto University

Tsunami magnetic fields arise when conductive sea water moves in the Earth's main magnetic field as a tsunami wave (e.g., Tyler, 2005). It has been revealed that tsunami electromagnetic fields are observed prior to the arrival of tsunami wave heights, which is useful for estimating tsunami wave heights and the direction of tsunami propagation(e.g., Lin et al. 2021). Therefore, this phenomenon is expected to be applicable to tsunami early warning systems. However, there are some problems: the observation of tsunami electromagnetic fields is restricted to significant tsunami events because signal-to-noise ratio must be large enough to detect signals, and it is difficult to visually identify tsunami electromagnetic signals.

We attempted to detect tsunami electromagnetic fields using machine learning to solve these problems. As a first step, we focused on building machine learning models to determine whether the data includes tsunami electromagnetic fields or not. We selected supervised learning, which is one of the machine learning methods and prepared a large amount of training data. The training data consists of two types: one includes tsunami magnetic components, and the other does not. We calculated the tsunami magnetic components in the data by a numerical simulation method for tsunami electromagnetic fields (Minami et al. 2017), while we used the observation data when certain events did not involve tsunami electromagnetic fields. We associated these two types of data with their corresponding answer labels, and then they are training datasets. The answer labels are scalar values of 0 or 1; we set tsunami magnetic data as 1 and non-tsunami magnetic data as 0. We fed these datasets into the machine learning model and conducted training iterations. In the 1D-CNN model, a high accuracy of 85% was recorded on the test datasets (which were separated from the training datasets to validate the model's performance). Accuracy, in this context, represents the correspondence between the input data and the answer labels. In this research, we inputted the real observation data into our machine learning model and assessed its performance. In addition, besides our existing model designed for 1-minute sampling data, we developed a new machine learning model designed for 2-minute sampling data. It enabled us to utilize data observed at the northwest Pacific (NWP) observation point, which included tsunami electromagnetic fields associated with the 2006 and 2007 Kuril Islands earthquakes. As a result, our model successfully detected tsunami magnetic signals within the data at NWP for that period. In this presentation, we will report more detailed our model's performance.

津波誘導磁場とは、良導体である海水が津波として運動する際に、地球主磁場を横切ることで生じる磁場変動のことである (e.g., Tyler, 2005)。津波誘導磁場については、津波波高に先行して観測されること、津波誘導磁場が津波波高や伝播方向の推定に役立つことが明らかとなり、津波早期警戒への応用が期待されている (e.g., Lin et al. 2021)。しかしながら、これまでに報告された津波誘導磁場の観測例は S/N 比の大きくなる巨大津波イベントに限定されてきた。津波誘導磁場の津波早期警戒への応用のためには、目視による津波誘導磁場の同定が困難な津波イベントにおいても、津波誘導電磁場を検出する手法を確立することが重要である。

本研究では、上の要請に応えるため、機械学習を用いて磁場時系列中の津波誘導磁場を検出することを試みた。研究の第一段階として、津波誘導磁場の有無を判別する機械学習モデルの作成に取り組んだ。機械学習の一種である教師あり学習を採用し、機械学習モデルの学習用データを大量に作成した。学習用データは、津波誘導磁場成分を含むものと、含まないもの 2 種類を同数作成した。磁場データの津波起因成分は、津波電磁場シミュレーション (Minami et al. 2017) により作成し、平時の観測磁場データを、津波起因成分を含まない磁場データとして使用した。これら 2 種類のデータそれぞれに正解ラベルを付し、学習用データとして機械学習モデルに与え、訓練を繰り返した。ここでの正解ラベルとは、0 か 1 のスカラー値で、津波誘導磁場を含むデータに 1 を、含まないデータに 0 を付した。1 次元畳み込みニューラルネットワークを用いた機械学習モデルでは、テストデータ (訓練用データとは別に取り分けた、機械学習モデルの性能検証のためのデータ) に対して約 85% と高い正解率を記録した。ここでの正解率とは、与えた入力データと正解ラベルとの一致率である。本研究では、作成した機械学習モデルを実際の磁場観測データに適用して、津波誘導磁場の検出精度を確かめた。2006, 2007 年千島沖地震に伴って発生した津波イベントを対象に、毎分値データを用いて作成した機械学習モデルをフィリピン海で得られた磁場データに、また、毎 2 分値データを用いて作成した機械学習モデルを北西太平洋海底観測点 (NWP) で得られた磁場データに応用した。その結果、NWP において、津波誘導磁場現象発生に該当する期間に、津波誘導磁場が存在するという検出結果を得た。本発表では、実際の磁場観測データによって検証した機械学習モデルの検出精度について、より詳しく報告する。