Serpentine Landslide Distribution Derived from Magnetic Measurement

著者	Kido Yukari
journal or publication title	Proceedings, International Symposium of the Kanazawa University 22st-Century COE Program
volume	1
page range	375-378
year	2003-03-16
URL	http://hdl.handle.net/2297/6433

Proceedings: International Symposium of the Kanazawa University 21st-Century COE Program Vol. 1 (2003)
Edited by Naoto KAMATA

Serpentine Landslide Distribution Derived from Magnetic Measurement

YUKARI KIDO
Institute for Frontier Research on Earth Evolution (IFREE)
Japan Marine Science and Technology Center (JAMSTEC)
3173-25, Showa-machi, Kanazawa-ku, Yokohama-city, Kanagawa, 236-0001, JAPAN

Abstract - Using a fine-scale magnetic anomaly data based on high density air-borne surveys, field susceptibility data, and rock magnetic measurements, we have identified several dipole anomalies aligned east-west direction exactly on the Kurosegawa Tectonic Zone, which constitutes a part of an accretionary prism in the southwest Japan. A plausible candidate for the magnetic source is serpentine diapers associated with dehydration of subducted slabs. Surface geological evidences also suggest the existence of serpentines and landslide mass distribution.

I Introduction

The Frontier Research Program has investigated the subduction history of the Nankai Trough during cooperative experiments onland in Shikoku and in the northern Shikoku Basin, using the R/V Kairei, since 1997. In 1999 experiment, 170 OBSs were deployed along seismic lines totaling 500 km in length, to reveal the crustal structure beneath the Nankai trough and Shikoku. The track lines extended across the Kurosegawa Tectonic Zone (abbreviated as KTZ), which is composed of ultramafic rocks with an associated high magnetic dipole anomaly. More than 100 ultramafic rock samples were collected along Route193 in the Kisawason and Sakashu areas within the KTZ located No.4 in Fig.1(a). Magnetic intensity, sonic velocity, density and petrologic properties were subsequently measured on 100 core specimens. The localities of landslide zone with a Bouguer gravity anomaly, geomagnetic dipole anomaly and an apparently aseismic area were found to coincide with the distribution of serpentinite in the KTZ.

Geophysical data have produced a relatively detailed image of these bodies and deeper crustal structure. However, while gravity and geomagnetic data are of low resolution compared with seismic data, it is important for qualitative interpretation that they are not interpreted contradictorily. In this paper, we estimate the geomagnetic dipole anomaly of the Shikoku region using geomagnetic and other geophysical data obtained previously, and the source of the anomalies. Generally the predominant magnetic anomaly observed onland in Shikoku is approximately flat, and the amplitude is smaller than the corresponding value observed offshore. However, we document some large magnetic dipole anomalies in Shikoku which coincide strongly with the surface geology.

II. Shikoku magnetic dipole anomaly

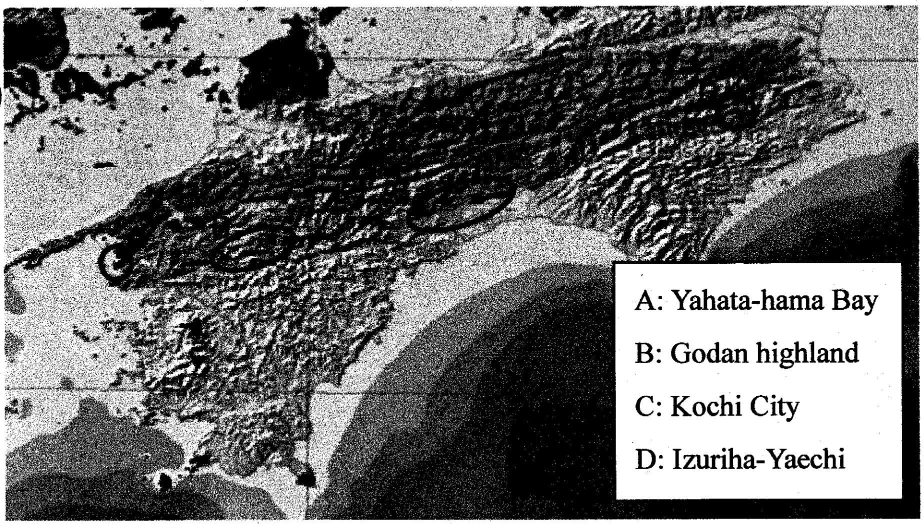
Dipole anomalies are shown clearly in Figure 1, the geomagnetic anomaly map of the Shikoku region comprising geomagnetic data compiled by the Coordinating Committee for Coastal and Offshore Geoscience Programs in East and Southeast Asia (CCOP) of the Geological Survey of Japan [1]. Though the geomagnetic signature of Shikoku is almost flat, there are four distinct dipole anomalies. These are typical magnetic dipole anomalies observed in the Northern Hemisphere in response to a pair of negative and positive intensities.

The other ten dipoles are within the Kurosegawa Tectonic Zone (Table1). The easternmost Shikoku of these is located near an ultramafic complex of the Kurosegawa tectonic belt, having a 150 nT maximum amplitude and 20 km wavelength centered in Kisawa village, near Sakashu in Tokushima Prefecture (hereafter referred to as the "Yaechi anomaly"). The "Engyou-ji anomaly", which is centered at the city of Kochi, in huge serpentine quarry zone, a region of karst topography in the Godan highlands near the Ehime–Kochi prefectural boundary (the "Godan anomaly") are on the KTZ (Fig.2). Table 1 summarizes the data pertaining to the four recognizable anomalies. The correspondence between geological with landslide mass distribution and magnetic features is particularly notable because there are no large volcanoes in Shikoku.

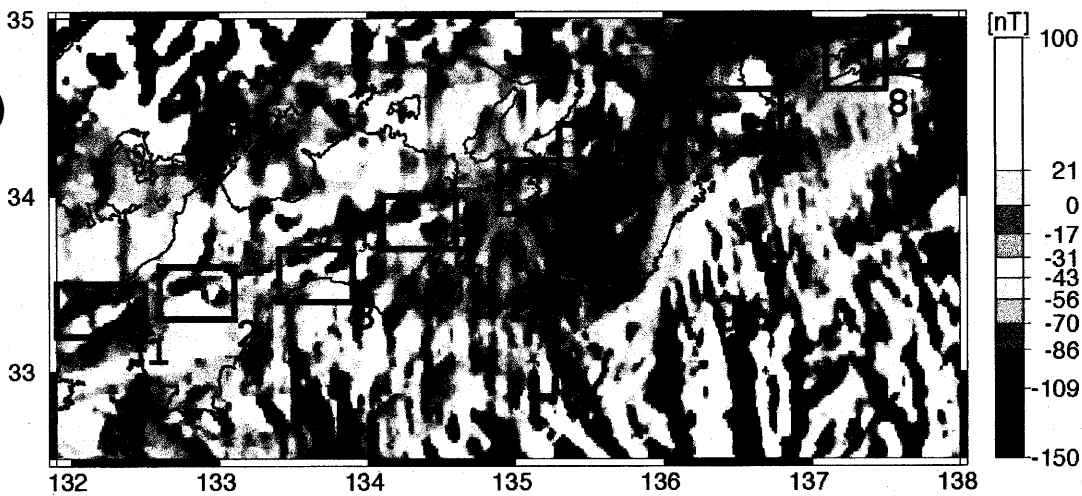
III. Magnetic source inversion and measurement

We apply a magnetic inversion (Kido, Yuen, Cadek, and Nakakuki [2]) to one of the dipole anomalies found here, and hypothesize the magnetic source to be a spheroidal shape standing parallel and slightly inclined to the tectonic line. We also performed geophysical investigation with susceptibility meter, sampling along KTZ and rock magnetic measurements. More than 100 ultramafic rock samples were collected along KTZ. Magnetic intensity, susceptibility, sonic velocity, density and petrologic properties were subsequently measured on 100 core specimens and thin sections. The source is magnetized roughly in the same direction as the current geomagnetic field. This implies that the induced magnetization is the dominant, rather than the remanent component. Recent geological surveys, sampling both on land and on the seafloor indicate the existence of serpentinized materials between the trench and the volcanic front [e.g., Fryer, Pearce, and Stokking [3]]. These materials are thought to come from the shallow mantle wedge as a diapir [e.g., Fryer and Fryer, [4]; Maekawa, Shozui, Ishii, Fryer, and Pearce [5]] because of their low density [Toft, Arkini-Hamed, and Haggerty [6]] caused by reactions with water supplied by subducted slabs [e.g., Tatsumi [7]]. In some regions, these serpentine diapirs form a chain of small

(a)


A: Yahata-hama Bay
B: Godan highland
C: Kochi City
D: Izuriha-Yaechi

(b)


35
34
33
132
133
134
135
136
137
138
[nT]
100
21
0
-17
-31
-43
-56
-70
-86
-109
-150
1
2
3
8

(c)

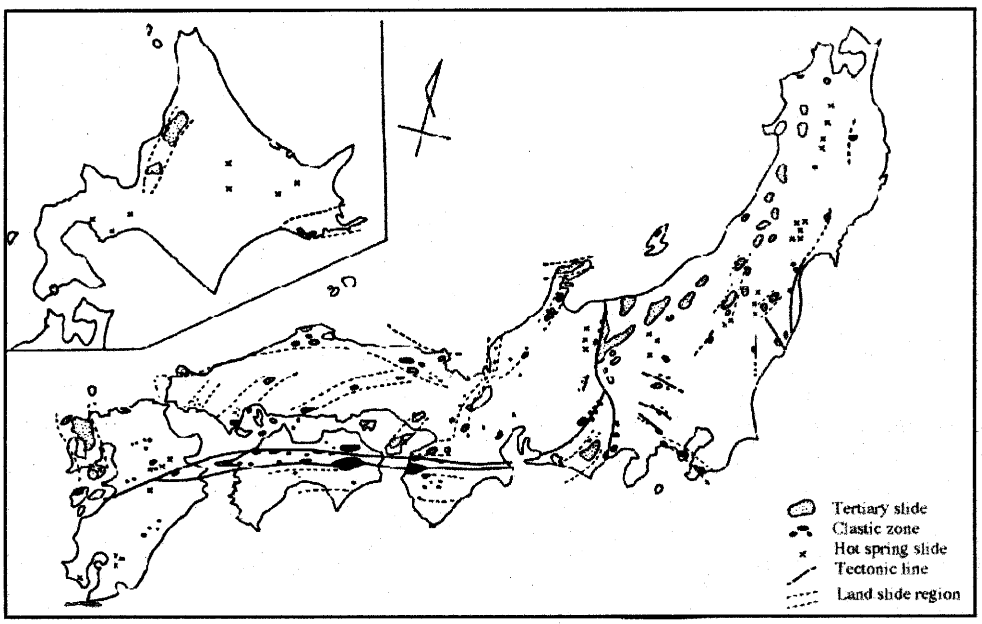

Tertiary slide
Clastic zone
Hot spring slide
Tectonic line
Land slide region

Figure 1(a): Geological maps of SW Japan (GSJ [10]). Gray scale indexes display that ultramafic, sedimentary rocks, plutons, volcanic rocks, and red circles are area of research sites. (b): Geomagnetic anomaly map of SW Japan. Magnetic dipole position is displayed by box. No.1 to 4 Box are coincident with A to D in Fig1(a), respectively. (c): Landslide distribution of Japan. Clastic zone filled with black color in Southwestern Japan coincide with magnetic dipole anomaly site No.1 through 4 (in (b)), and serpentine outcrops No. A through D (in (a)).

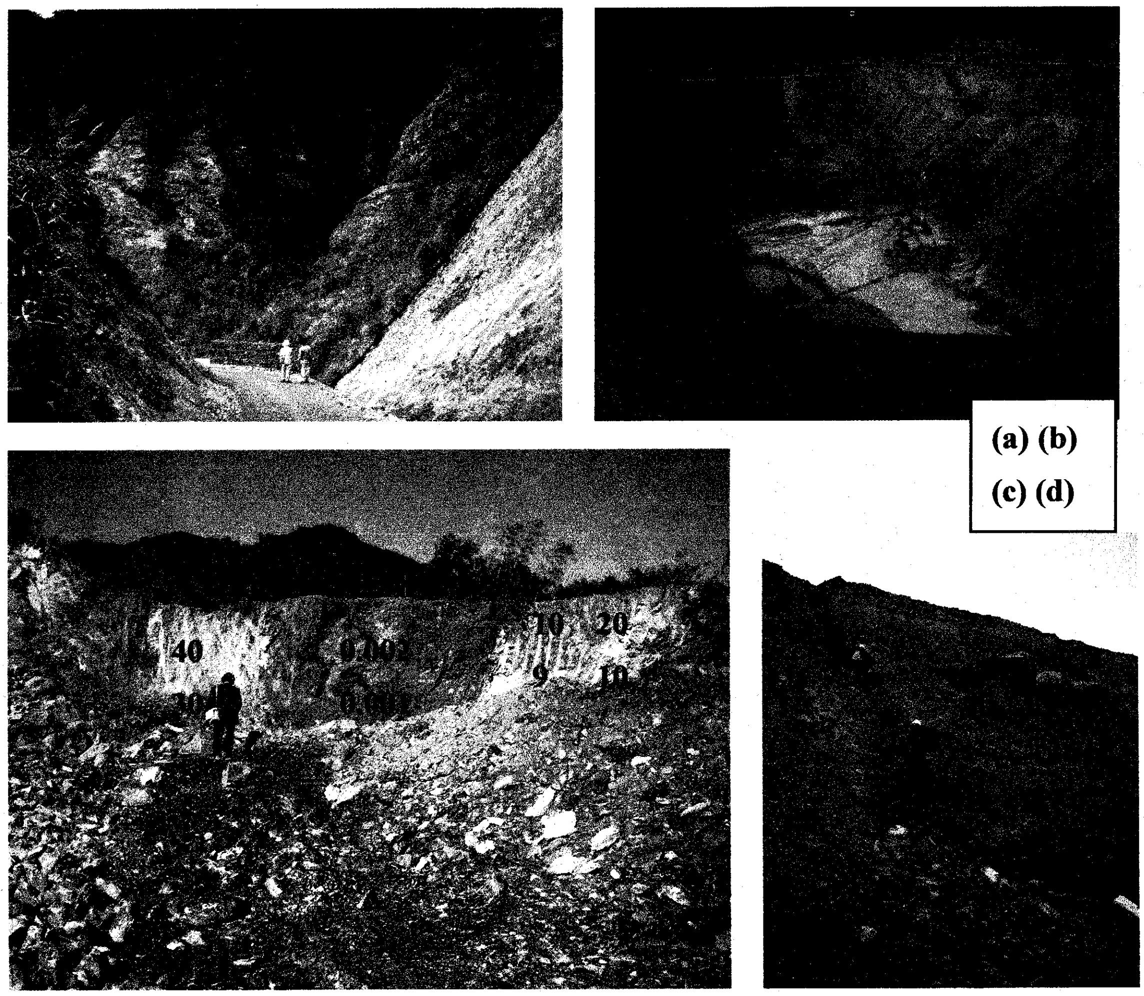


Figure 2(a): Huge serpentine outcrops located at the southern slope of Godan highland, just like a “serpentine road”, in Ehime Prefecture (region B in Fig.1a). (b): In "Engyou-ji anomaly", it was proven that the large-scale serpentinite which is considerably homogeneous from field work investigation and sampling in the quarry in the central Kochi city. (c): The boundary of the quarry of (b) can be easily detected by handy susceptibility meter (attached number; S.I unit). (d): Landslide slope at the quarry (in the same in (b)).

seamounts parallel to the trench [Fryer, Pearce, and Stokking [3]].

Since serpentinization process accompany magnetite formation [O'Hanley [8]], serpentine diapirs are expected to have a relatively high magnetic susceptibility [Toft, Arkini-Hamed, and Haggerty [6], Nazarova [9]]. This enables us to observe them as a series of magnetic dipole anomalies. Southwestern Japan is a suited field for this purpose because a fine-scale magnetic data set [GSJ [1]] is available and there is a wide enough (120km) magnetically silent zone between the highly magnetized oceanic crust and the volcanic front (Fig. 1b). In this point of view, we cast around for such signals using air-borne based magnetic data, then estimate the aspects of the magnetic source by using an inversion in discussion about the tectonic framework of this region.

Along the KTZ we have performed geophysical investigation with magnetic susceptibility meter and rock sampling by drilling tool. Magnetic susceptibility meter SM-30 are handy and useful tool for field measurement of outcropping rocks, drill cores or rock samples. It is also available to determine a boundary of rock types, volume of magnetic minerals and alteration ratio. Fig. 3c shows that an example of magnetic susceptibility data of one of dipole areas at Aitani serpentine quarry of Engyoji, Kochi City. Numbers attached photo are value indicating strong serpentine minerals and weak sedimentary rocks. Most normal serpentinite include high susceptibility value (10-3~10-2 emu). It's also clear indicator of alteration ratio.

TABLE I

Position, amplitude of Shikoku magnetic dipole anomalies. Name description, location of latitude and longitude, profile amplitude and diameter of dipole anomaly are presented.

	area	center (Lat, Lon)	Amplitude (nT)	Dipole size (km)
1`	Cape Sada	N33d15m, E132d15m	80nT	20km
2	Shikoku Karust	N33d27m, E132d55m	60nT	20km
3	Engyou-ji	N33d35m, E133d35m	45nT	20km
4	Yaechi	N33d52m, E134d20m	100nT	30km
5	West Wakayama	N34d08m, E135d12m	30nT	15km
6	West Wakayama	N34d15m, E135d25m	50nT	20km
7	Shima Pen.	N34d27m, E136d30m	70nT	20km
8	Atsumi Pen.	N34d42m, E137d18m	30nT	15km
9	Lake Hamana	N34d50m, E137d35m	50nT	20km
10	Mt.Chausu	N35d10m, E137d38m	120nT	20km

IV. Summary and Conclusions

Results of inversion method are coincident with magnetic susceptibility value obtained at Region D (Box 4), and also estimated volume of surface magnetic distribution by boundary condition using a susceptibility meter. Concerning the fact that magnetic dipole anomalies are distributed only along the KTZ, we propose here two scenarios. One is that the serpentine diapers that came up from the mantle wedge were once trapped at the underground KTZ and then were upraised to the near surface along the KTZ. The other is that Triassic serpentine seamounts are incorporated with sedimentary accretion, which have formed the KTZ. In this connection, compatibility of the magnetized direction with the IGRF indicates dominance of the induced magnetization because remanent magnetization can not keep its direction during such complex upwelling or accretion processes. A linear magnetic anomaly with a small amplitude is apparently observed along the western-half of the KTZ (Fig. 1b). This implies that the KTZ itself is slightly magnetized for a widely diffused part of the serpentine diapers due to the accretion process or possible transcurrent fault activity in the past.

Acknowledgements

The authors are greatly indebted to Drs. Fujioka, Furuta and Zhong Zheng, Profs. Ishizuka and Shibuya for their kind field guidance and many suggestions for this work, Profs. Murakami and Yoshikura for their valuable comments, and Dr. M. Kido, for providing a program code of the magnetic inversion

References

[1] GSJ (Geological Survey of Japan) and Coordinating CCOP (1996) Magnetic Anomaly Map of East Asia, 1:4,000,000 CD-ROM Version.

[2] Kido, M., D. A. Yuen, O. Cadek, and T. Nakakuki, Mantle viscosity derived by genetic algorithm using oceanic geoid and tomography for whole-mantle versus blocked-flow situations, *Phys. Earth Planet. Inter.*, Vol. 107, pp. 307-326, 1998.

[3] Fryer, P., J. A. Pearce, L. B. Stokking, *Proc. ODP, Sci. Results*, Vol. 125: College station, TX (Ocean Drilling Program), 1992.

[4] Fryer, P., and G. J. Fryer, in Seamounts, Islands, and Atolls, B. Keating, P. Fryer, R. Batiza and G. W. Boehlert eds., *AGU Monogr.*, Vol. 43, pp. 61-69, 1987.

[5] Maekawa, H., H. Shozui, M. Ishii, P. Fryer, and J. A. Pearce, Blueschist metamorphism in an active subduction zone, *Nature*, Vol. 364, pp. 520-523, 1993.

[6] Toft, P. B., J. Arkini-Hamed, and S. E. Haggerty, The effect of serpentinization on density and magnetic susceptibility: a petrophysical model, *Phys. Earth Planet. Inter.*, Vol. 65, pp. 137-157, 1990.

[7] Tatsumi, Y., Migration of fluid phases and genesis of basalt magmas in subduction zones. *J. Geophys. Res.*, Vol. 94, pp. 4697-4707, 1989.

[8] O'Hanley, D. S., Serpentinites: Records of petrologic and tectonic history, Oxford Univ. Press, pp. 277, 1996.

[9] Nazarova, K. A., Serpentinized peridodites as a possible source for Oceanic magnetic anomalies, *Marine Geophys. Res.*, Vol. 16, pp. 455-462, 1994.

[10] GSJ (Geological Survey of Japan), Geological Map of Japan 1:1,000,000 CD-ROM Version, 3rd edition, 1995.