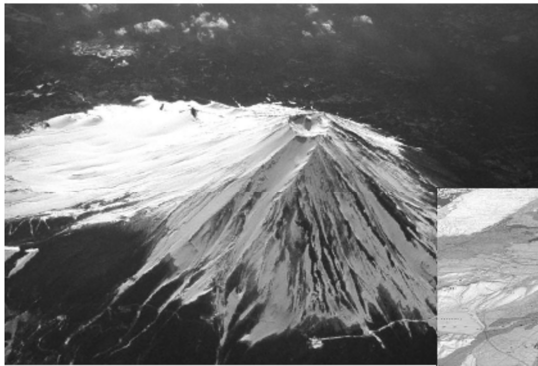
Appendix 3

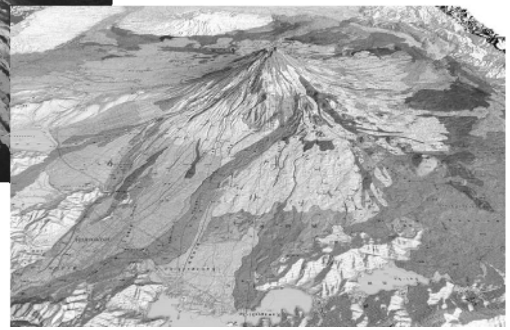
Seamless Geology

Seamless Geological Map (1:1,000,000) of Southeast Asia for ASEAN Mineral Resources Database

Yutaka TAKAHASHI (Geological Survey of Japan)

Topographic map vs Geologic map





Seamless Geological Map (1:1,000,000) of Southeast Asia for ASEAN Mineral Resources Database

I. Introduction

II. CCOP Digital Geologic Map of East and Southeast Asia (1:2,000,000)

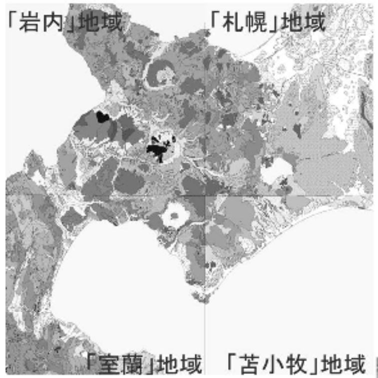
III. Geological Maps (1:1,000,000) of ASEAN countries from OneGeology and their original maps

1. **Geological Map of Vietnam, Laos and Cambodia**
2. **Geological Map of Thailand**
3. **Geological Map of Myanmar**

IV. Unified Legend for the Seamless Geological Map (1:1,000,000) of Southeast Asia for ASEAN Mineral Resources Database

V. Seamless Geological Map of Japan (1:200,000) and GeomapNavi based on the Seamless Geological Map

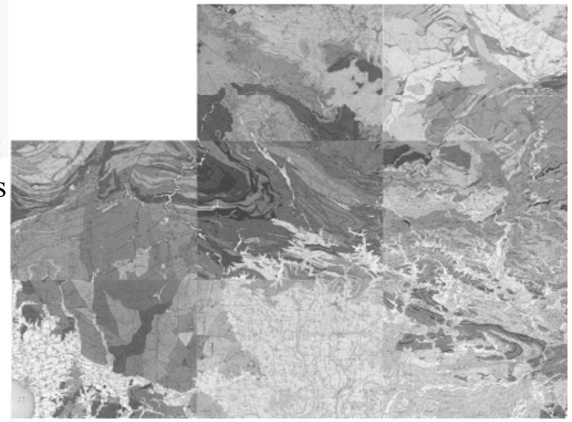
What is the Seamless Geologic Map?



1: 200,000 geologic maps

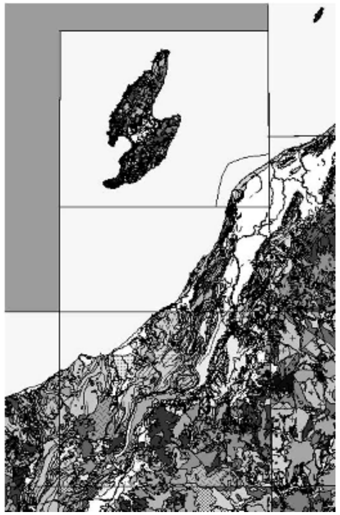
Original geologic maps is different each other

1 :50,000 geologic maps

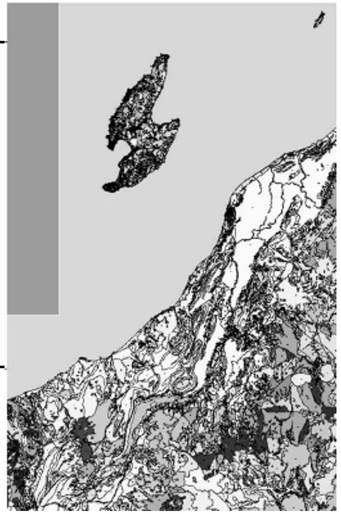


Why ?

Processes to harmonize



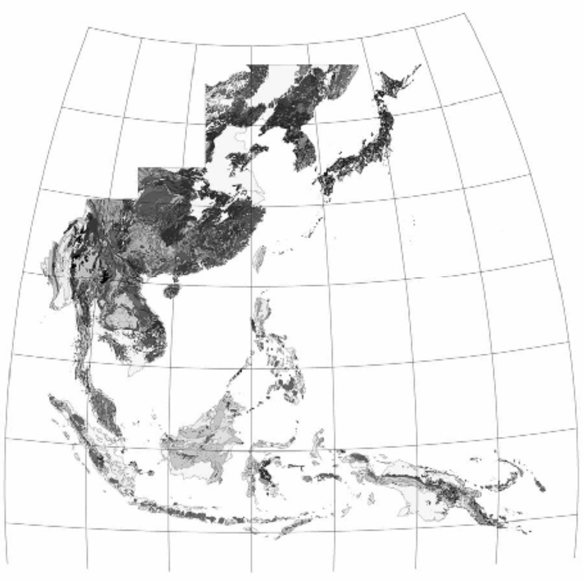
1. Digitization
2. Unified legend
3. Connect geologic boundaries



Legend of the CCOP Degital Geologic Map of East and Southeast Asia (1:2,000,000)

Q_S	CP_S	NQ_Vm	J_Vim	NQ_Pfi	Tr_Pf	Pt_Pm	EO_Ml
NQ_S	C3P_S	N_Vf	J_Vm	NQ_Pi	Tr_Pfi	APt_Pf	E_Mu
N3Q_S	C_S	N_Vfi	Tr_Vf	N_Pf	Tr_Pi	A_Pf	Pz1_Mi
N3Q1_S	DC_S	N_Vi	Tr_Vi	N_Pfi	Tr_Pm	A_Pi	Pz_Mi
N2Q1_S	D_S	N_Vim	Tr_Vim	N_Pi	Mz_Pf	A_Pm	Pz_Ml
N_S	SD_S	N_Vm	Tr12_Vf	N_Pim	Mz_Pfi	PE_Pf	Pz_Mu
Pg_S	S_S	N_Vu	Mz_Vf	N_Pm	Mz_Pi	Uk_Pf	Pt3_Mi
T_S	OS_S	Pg_Vf	PTr_Vfi	Pg_Pf	Mz_Pm	Uk_Pm	Pt3_Ml
KPg_S	O_S	Pg_Vfi	P_Vf	Pg_Pfi	PTr_Pf	Uk_Pu	Pt2_Mi
K_S	EO_S	Pg_Vim	P_Vfi	Pg_Pi	P_Pf	Pg_Mi	Pt2_Ml
JK_S	E_S	Pg_Vm	P_Vi	Pg_Pim	P_Pfi	K_Mi	Pt1_Mh
J3K1_S	Pz_S	T_Vf	P_Vim	Pg_Pm	P_Pi	K_Mu	Pt1_Mi
J_S	Pz2_S	T_Vfi	P_Vm	KPg_Pf	P_Pm	J_Mi	Pt1_Ml
J12_S	Pz1_S	T_Vim	P2_Vi	KPg_Pim	Pz2_Pf	Tr_Mi	Pt_Mh
TrJ_S	PEE_S	Cz_Vm	P2_Vm	K_Pf	Pz2_Pfi	Tr_Mu	Pt_Mi
Tr3J_S	Pt_S	KPg_Vf	CP_Vfi	K_Pfi	Pz2_Pi	Mz_Ml	Pt_Ml
Tr_S	PE_S	K_Vf	CP_Vi	K_Pi	Pz2_Pm	P_Mi	Pt_Mu
Tr3_S	Q_Vf	K_Vfi	C3P_Vi	K_Pm	Pz12_Pf	P_Mu	A_Mh
Tr12_S	Q_Vfi	K_Vi	OS_Vfi	JK_Pf	Pz12_Pu	CP_Mu	A_Mi
Mz_S	Q_Vi	K_Vm	E_Vi	JK_Pfi	Pz1_Pf	C_Mi	A_Ml
PTr_S	Q_Vim	JK_Vi	E_Vm	JK_Pi	Pz1_Pi	C_Mu	PE_Mh
PTr12_S	Q_Vm	JK_Vm	Pz2_Vf	J_Pf	Pz1_Pm	D_Mu	PE_Mi
CTr_S	Q_Vu	J3K_Vi	Pz12_Vf	J_Pfi	Pz_Pf	SD_Ml	PE_Ml
PzMz_S	NQ_Vfi	J_Vf	Pz_Vm	J_Pi	Pt3_Pf	S_Ml	PE_Mu
P_S	NQ_Vi	J_Vfi	Pt_Vm	J_Pm	Pt_Pf	OS_Mu	U
P2_S	NQ_Vim	J_Vi	Q_Pm	TrJ_Pf	Pt_Pfi	O_Ml	Water

II. CCOP Digital Geologic Map of East and Southeast Asia (1:2,000,000; 2nd Edition, Wakita et al., 2004)



Explanation of abbreviations for Legend of the CCOP Digital Geologic Map of East and Southeast Asia

Age Abbr.	Age
Q	Quaternary
N	Neogene
NQ	Neogene to Quaternary
N3Q	late Neogene to Quaternary
N3Q1	late Neogene to early Quaternary
N2Q1	middle Neogene to early Quaternary
Pg	Paleogene
T	Tertiary
Cz	Cenozoic
KPg	Cretaceous to Paleogene
K	Cretaceous
JK	Jurassic to Cretaceous
J3K	Late Jurassic to Cretaceous
J3K1	Late Jurassic to Early Cretaceous
J	Jurassic
J12	Early to Middle Jurassic
TrJ	Triassic to Jurassic
Tr3J	Late Triassic to Jurassic
Tr	Triassic
Tr3	Late Triassic
Tr12	Early to Middle Triassic
Mz	Mesozoic
PTr	Permian to Triassic
PTr12	Permian to Middle Triassic
CTr	Carboniferous to Triassic
PzMz	Paleozoic to Mesozoic
P	Permian
P2	Late Permian
CP	Carboniferous to Permian
C3P	Late Carboniferous to Permian
C	Carboniferous
DC	Devonian to Carboniferous
D	Devonian
SD	Silurian to Devonian
S	Silurian

Age Abbr.	Age
OS	Ordovician to Silurian
O	Ordovician
EO	Cambrian to Ordovician
E	Cambrian
Pz	Paleozoic
Pz2	Late Paleozoic
Pz1	Early Paleozoic
Pz12	Middle Paleozoic
PEE	Precambrian to Cambrian
PE	Precambrian
Pt	Proterozoic
Pt3	Late Proterozoic
Pt2	Middle Proterozoic
Pt1	Ealy PRoterozoic
A	Archean
Uk	Unknown age

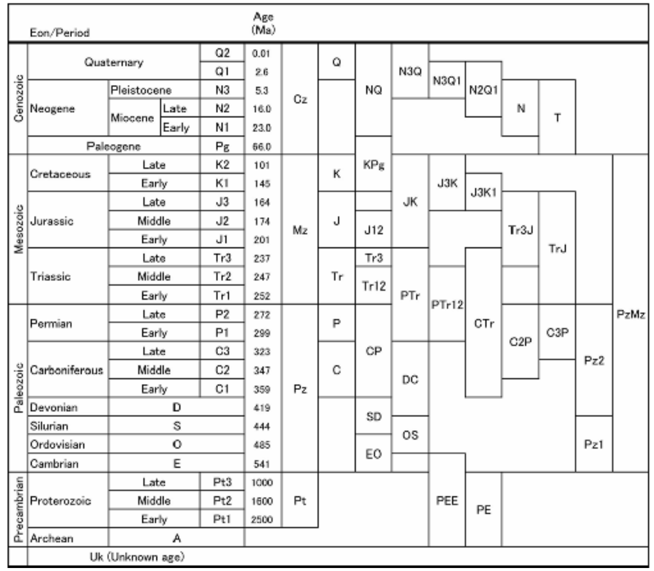
Lithologic Abbr.	Lithology
S	Sedimentary rocks
Vf	Felsic volcanic rocks
Vfi	Felsic to intermediate volcanic rocks
Vi	Intermediate volcanic rocks
Vim	Intermediate to mafic volcanic rocks
Vm	Mafic volcanic rocks
Vu	Volcanic rocks of unknown composition
Pf	Felsic pultonic rocks
Pfi	Felsic to intermediate pultonic rocks
Pi	Intermediate pultonic rocks
Pim	Intermediate to mafic pultonic rocks
Pm	Mafic pultonic rocks
Pu	Pultonic rocks of unkonwn composition
Mh	High grade metamorphic rocks
Mi	Intermediate grade metamorphic rocks
Ml	Low grade metamorphic rocks
Mu	Metamorphic rocks of unknown grade
U	Ultramafic rocks

List of Legend for each rock type for the CCOP Digital Geologic Map of East and Southeast Asia (1:2,000,000)

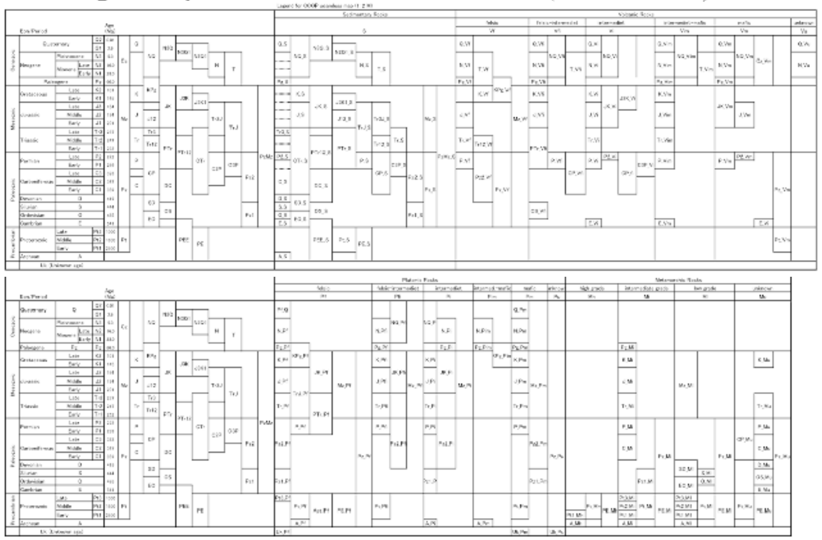
Sedimentary rocks				Volcanic rocks			
1	Q_S	31	D_S	51	JK_Vm	81	JK_Vm
2	NQ_S	32	SD_S	52	J3K_Vi	82	J3K_Vi
3	N3Q_S	33	S_S	53	J_Vf	83	J_Vf
4	N3Q1_S	34	OS_S	54	J_Vfi	84	J_Vfi
5	N2Q1_S	35	O_S	55	J_Vi	85	J_Vi
6	N_S	36	EO_S	56	J_Vim	86	J_Vim
7	Pg_S	37	E_S	57	J_Vm	87	J_Vm
8	T_S	38	Pz_S	58	Tr_Vf	88	Tr_Vf
9	KPg_S	39	Pz2_S	59	Tr_Vi	89	Tr_Vi
10	K_S	40	Pz1_S	60	Tr_Vim	90	Tr_Vim
11	JK_S	41	PEE_S	61	Tr12_Vf	91	Tr12_Vf
12	J3K1_S	42	Pt_S	62	Mz_Vf	92	Mz_Vf
13	J_S	43	PE_S	63	PTr_Vfi	93	PTr_Vfi
14	J12_S			64	P_Vf	94	P_Vf
15	TrJ_S			65	P_Vfi	95	P_Vfi
16	Tr3J_S			66	P_Vi	96	P_Vi
17	Tr_S			67	P_Vim	97	P_Vim
18	Tr3_S			68	P_Vm	98	P_Vm
19	Tr12_S			69	P2_Vi	99	P2_Vi
20	Mz_S			70	P2_Vm	100	P2_Vm
21	PTr_S			71	CP_Vfi	101	CP_Vfi
22	PTr12_S			72	CP_Vi	102	CP_Vi
23	CTr_S			73	C3P_Vi	103	C3P_Vi
24	PzMz_S			74	OS_Vfi	104	OS_Vfi
25	P_S			75	E_Vi	105	E_Vi
26	P2_S			76	E_Vm	106	E_Vm
27	CP_S			77	Pz2_Vf	107	Pz2_Vf
28	C3P_S			78	Pz12_Vf	108	Pz12_Vf
29	C_S			79	Pz_Vm	109	Pz_Vm
30	DC_S			80	Pt_Vm	110	Pt_Vm

Plutonic rocks				Metamorphic rocks			
116	Q_Pm	147	Mz_Pf	185	Pg_Mi	216	Pt_Mi
117	NQ_Pfi	148	Mz_Pfi	186	K_Mi	217	Pt_Ml
118	NQ_Pi	149	Mz_Pi	187	K_Mu	218	Pt_Mu
119	N_Pf	150	Mz_Pm	188	J_Mi	219	A_Mh
120	N_Pfi	151	PTr_Pf	189	Tr_Mi	220	A_Mi
121	N_Pi	152	P_Pf	190	Tr_Mu	221	A_Ml
122	N_Pim	153	P_Pfi	191	Mz_Ml	222	PE_Mh
123	N_Pm	154	P_Pi	192	P_Mi	223	PE_Mi
124	Pg_Pf	155	P_Pm	193	P_Mu	224	PE_Ml
125	Pg_Pfi	156	Pz2_Pf	194	CP_Mu	225	PE_Mu
126	Pg_Pi	157	Pz2_Pfi	195	C_Mi		
127	Pg_Pim	158	Pz2_Pi	196	C_Mu		
128	Pg_Pm	159	Pz2_Pm	197	D_Mu		
129	KPg_Pf	160	Pz12_Pf	198	SD_Ml		
130	KPg_Pim	161	Pz12_Pu	199	S_Ml	Ultramafic rocks	
131	K_Pf	162	Pz1_Pf	200	OS_Mu	229	U
132	K_Pfi	163	Pz1_Pi	201	O_Ml		
133	K_Pi	164	Pz1_Pm	202	EO_Ml		
134	K_Pm	165	Pz_Pf	203	E_Mu		
135	JK_Pf	166	Pt3_Pf	204	Pz1_Mi		
136	JK_Pfi	167	Pt_Pf	205	Pz_Mi		
137	JK_Pi	168	Pt_Pfi	206	Pz_Ml		
138	J_Pf	169	Pt_Pm	207	Pz_Mu		
139	J_Pfi	170	APt_Pf	208	Pt3_Mi	Water	
140	J_Pi	171	A_Pf	209	Pt3_Ml	230	water
141	J_Pm	172	A_Pi	210	Pt2_Mi		
142	TrJ_Pf	173	A_Pm	211	Pt2_Ml		
143	Tr_Pf	174	PE_Pf	212	Pt1_Mh		
144	Tr_Pfi	175	Uk_Pf	213	Pt1_Mi		
145	Tr_Pi	176	Uk_Pm	214	Pt1_Ml		
146	Tr_Pm	177	Uk_Pu	215	PT_M		

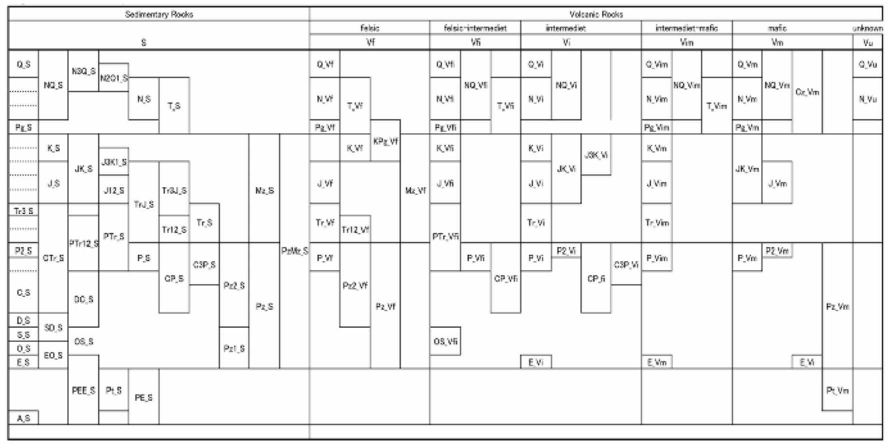
Geologic Ages for the CCOP Digital Geologic Map of East and Southeast Asia (1:2,000,000)



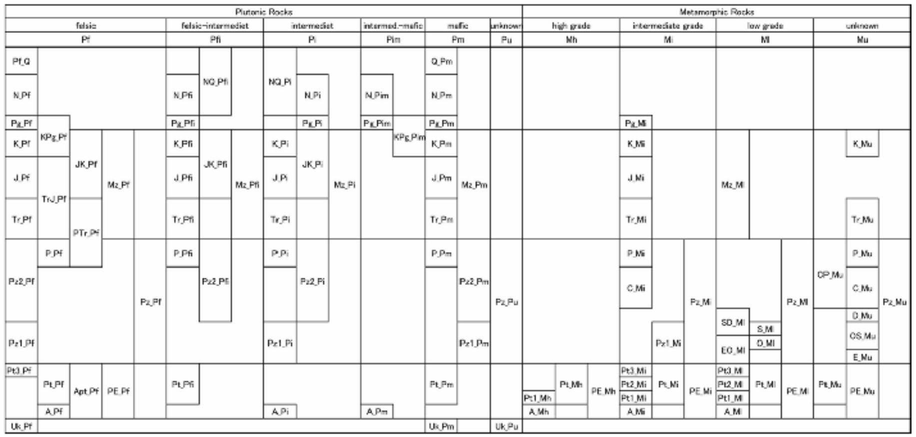
Compiled legend for each rock type of the CCOP Digital Geologic Map of East and Southeast Asia (1:2,000,000)



Legend (part 1 of rock facies) for the CCOP Digital Geologic Map of East and Southeast Asia (1:2,000,000)



Legend (part 2 of rock facies) for the CCOP Digital Geologic Map of East and Southeast Asia (1:2,000,000)



OneGeology

Making geological map data for the Earth accessible

A project to make web-accessible
the best available geological map data worldwide
at a scale of about 1:1 million

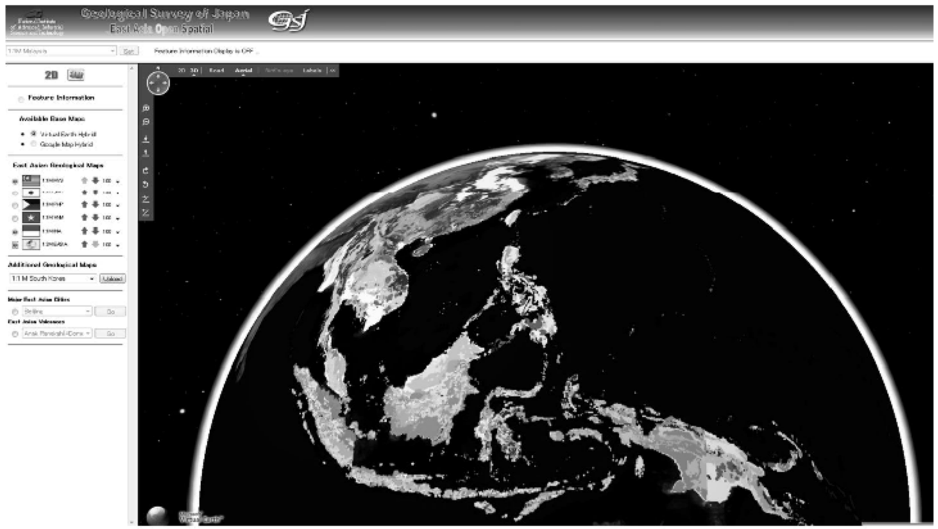
III. Geological Map (1:1,000,000) of ASEAN countries from OneGeology and their original maps

OneGeology provides the Geological Maps of ASEAN countries based on Geological Maps of each country (around1:1,000,000) with
different legend.

Geological Maps (1:1,000,000) of ASEAN countries are more precise compared with the CCOP digital Geologic Map (1:2,000,000). Therefore, they are useful for the base maps of ASEAN Seamless Geological Map (1:1,000,000).

脇田1

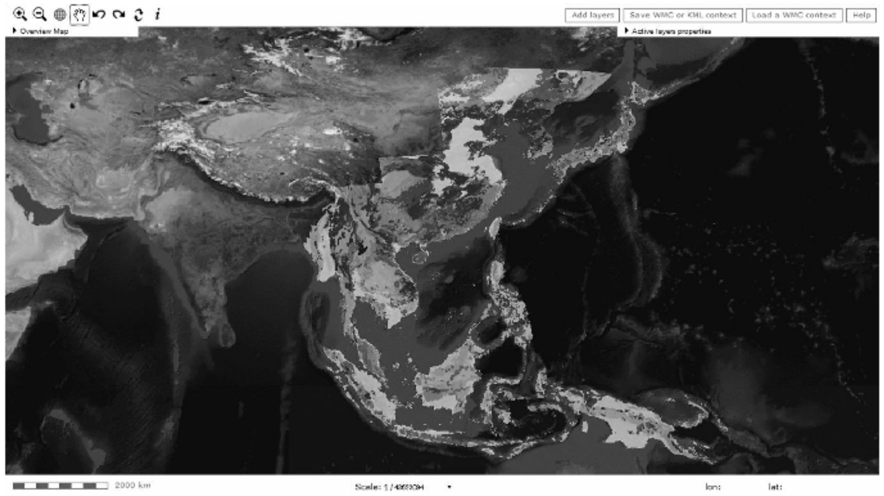
OneGeology ASIA



スライド 16

脇田1　GSJはまず、AISTサーバー上にCCOP OneGeology用にWMS portalを構築した。
脇田 浩二, 2009/04/08

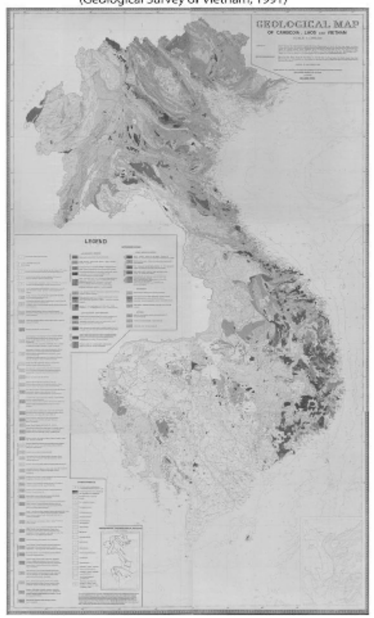
1:2 M Geological Map of East Asia



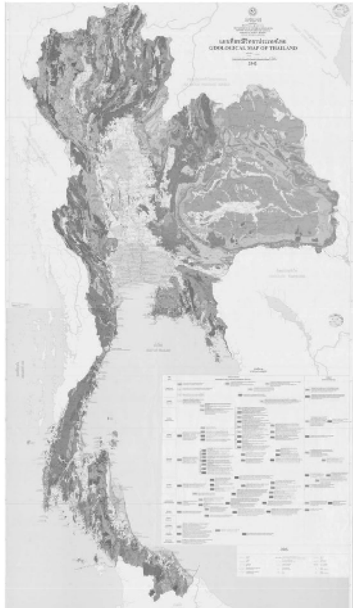
Activities of OneGeology Asia

- Participation from the kick-off meeting in UK 2007
- More than 10 countries are nominated in 1-G
- 1:2 million geologic map of E & SE Asia is presented
- 1:1million geolgic maps of Indonesia, Philippines, Korea, Japan, Thailand, and Vietnam are presented

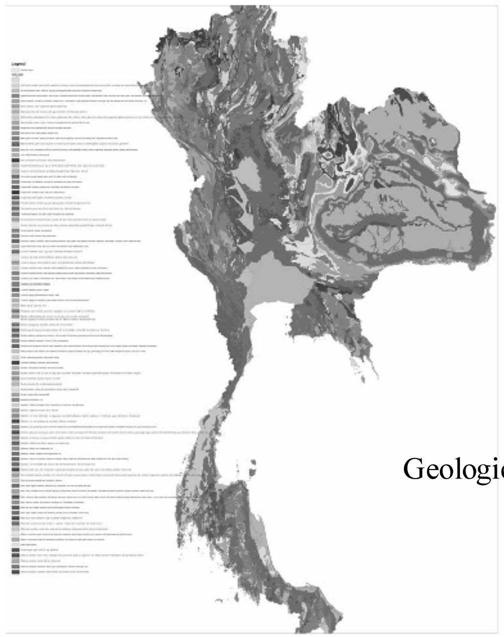
Geological Map of Cambodia, Laos and Vietnam (1:1,000,000)
(Geological Survey of Vietnam, 1991)



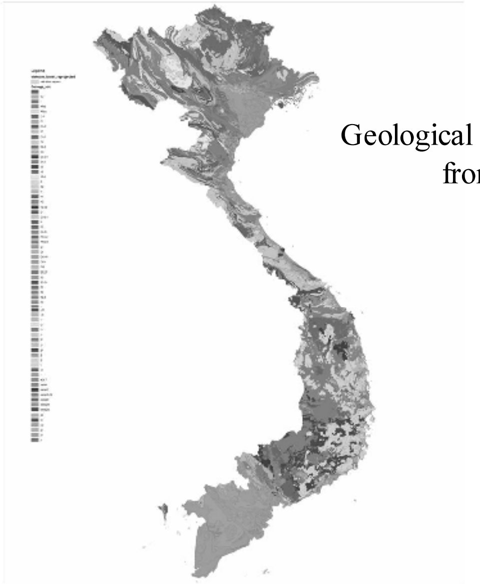
Geological Map of Thailand
(1:1,000,000; DMR, 1999)



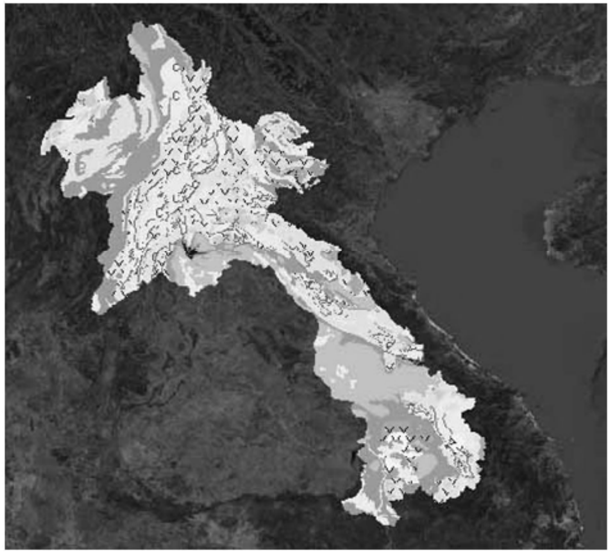
Geologic map of Thailand (1,000,000)
from OneGeology

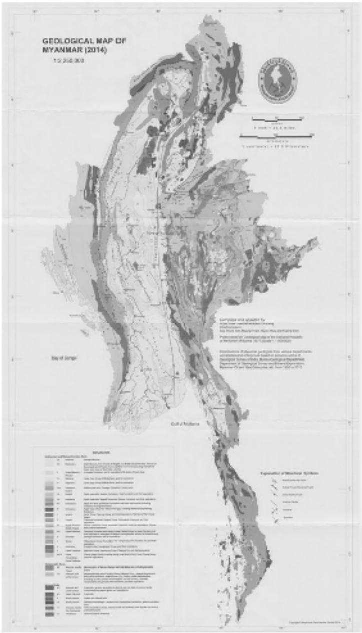


Geological Map of Vietnam (1:1,000,000)
from OneGeology



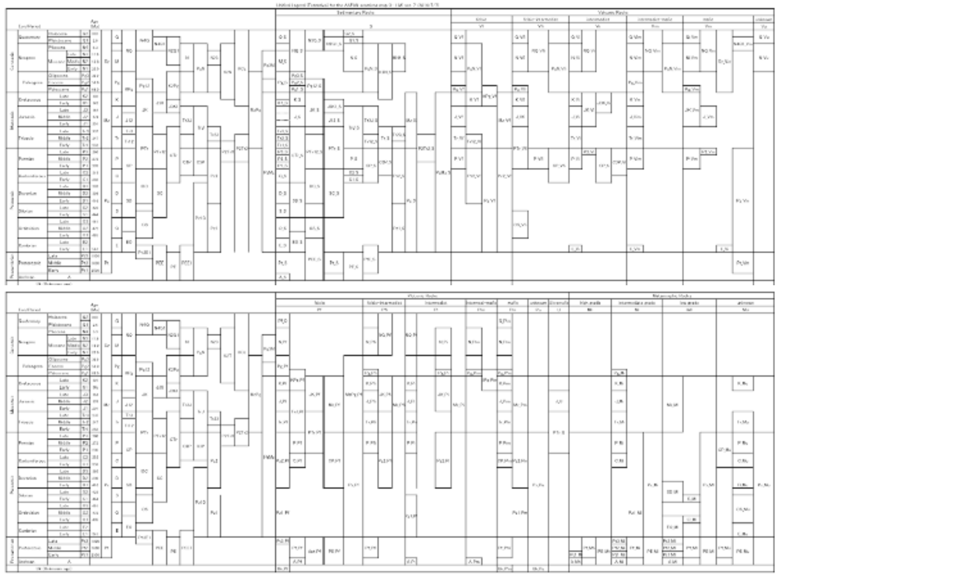
Geologic Map of Laos (1:1,000,000) from OneGeology

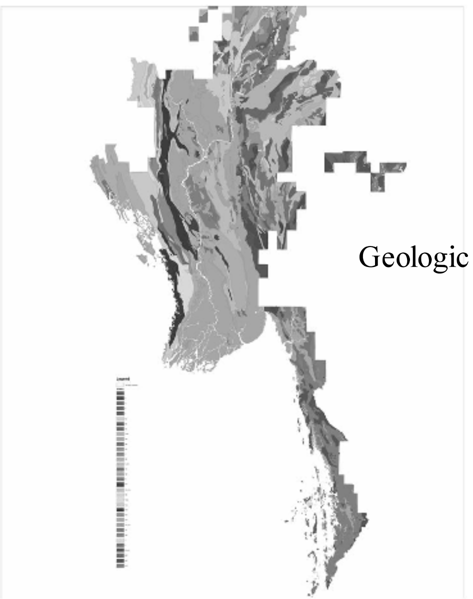




Geological Map of Myanmar
(1:2,250,000)
by Myanmar Geosciences
Society (2014)

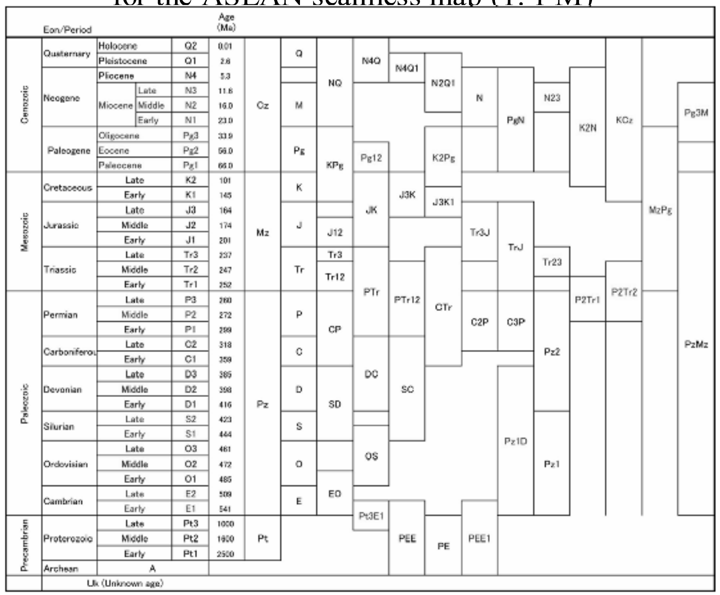
IV. Unified Legend (tentative) for the Seamless Geologic Map of East and Southeast Asia (1:1,000,000)



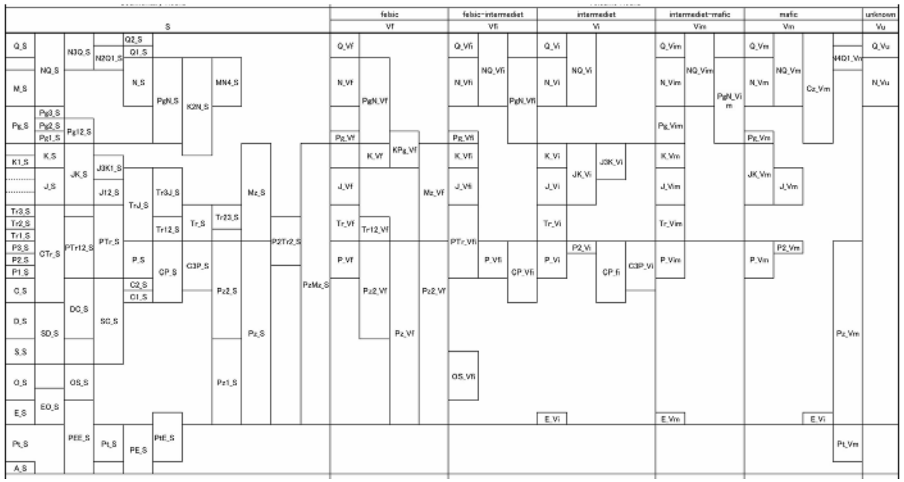


Geologic Map of Myanmar (1:1,000,000)
from OneGeology

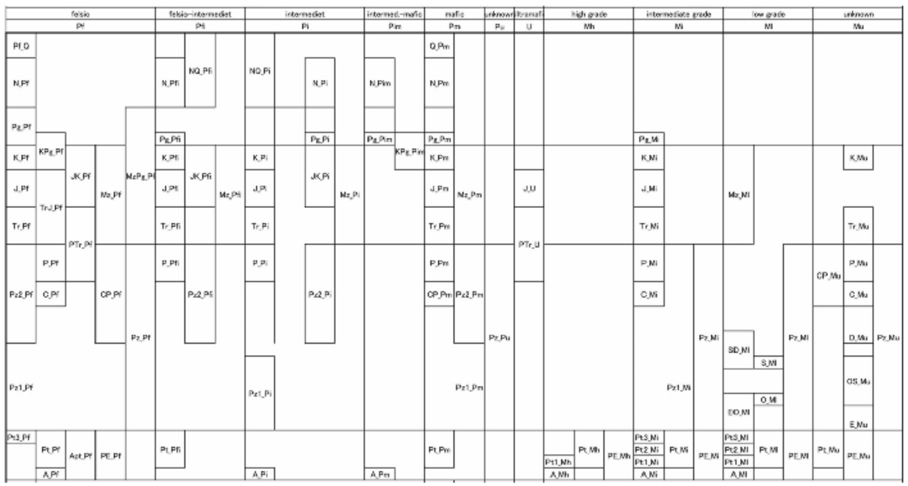
Unified Legend (geologic ages) for the ASEAN seamless map (1: 1 M)



Part of the Unified Legend (rock facies) for the ASEAN seamless map (1: 1 M)



Part of the Unified Legend (rock facies 2) for the ASEAN seamless map (1: 1 M)

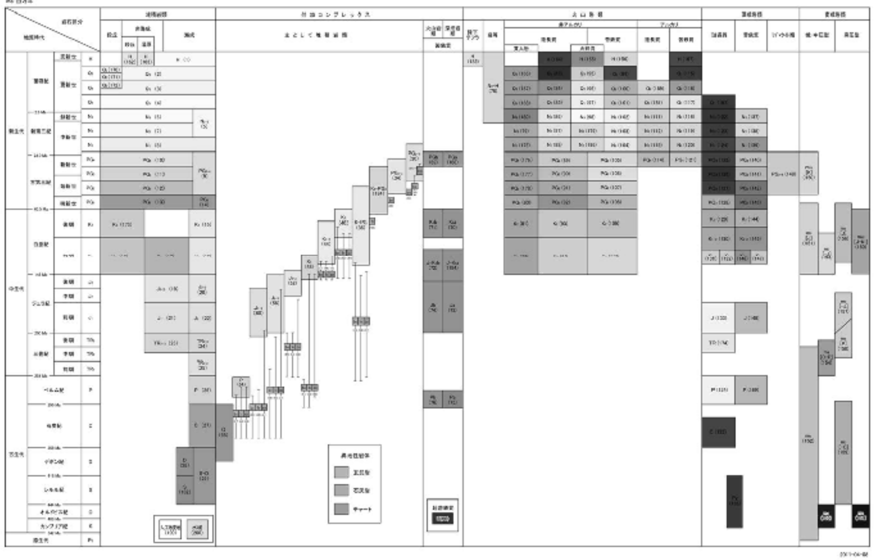


V. Seamless Geological Map of Japan and GeomapNavi by the Geological survey of Japan based on the Seamless Geological Map

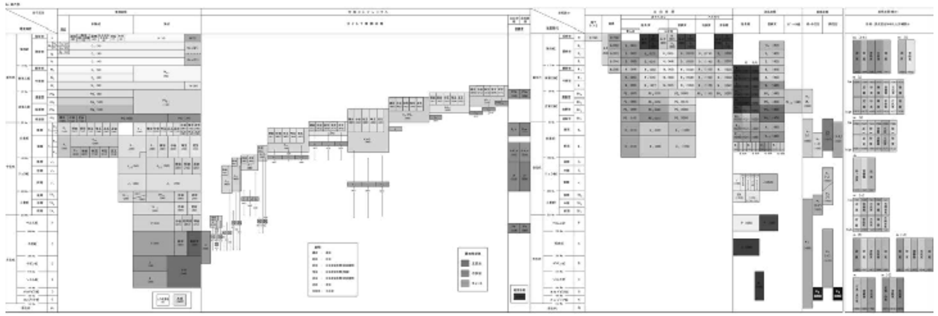
URL: https://gbank.gsj.jp/geonavi/geonavi.php

Seamless Geologic Map of Japan (1:200,000; basic version)

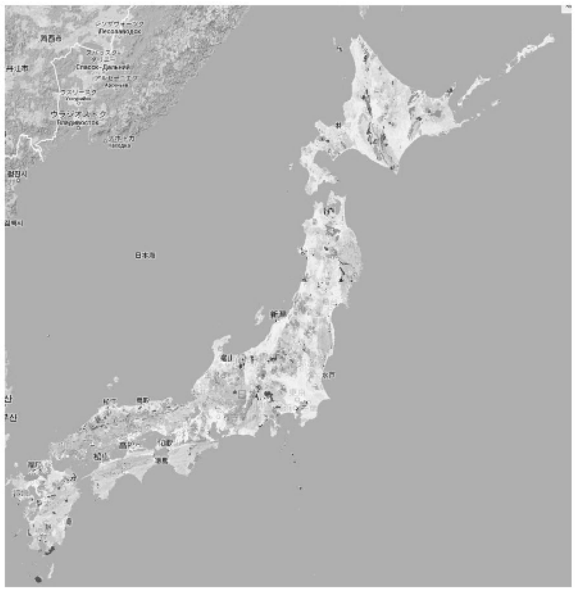
Unified Legend for Seamless Geological Map of Japan (1:200,000; basic version)



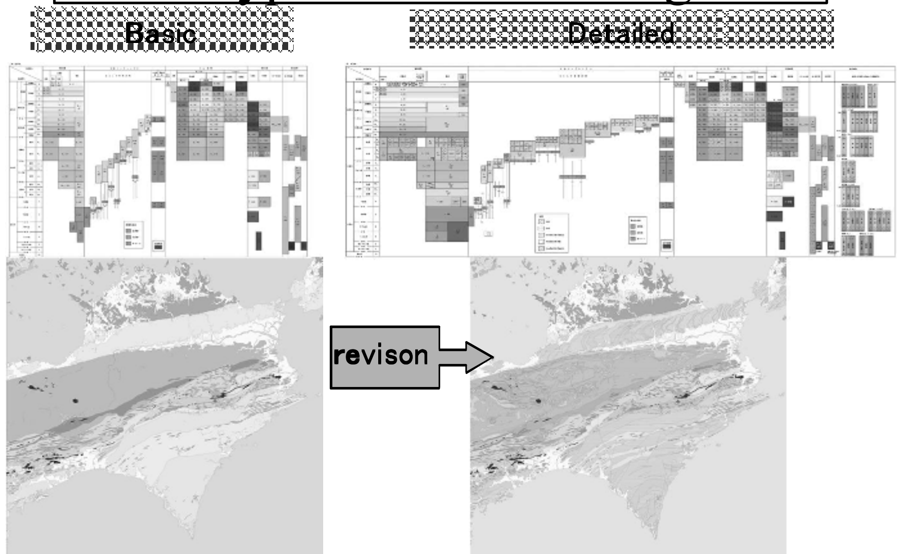
Unified Legend for Seamless Geological Map of Japan (1:200,000; detailed version)



Seamless Geologic map of Japan (1:200,000; detailed version)



Two types of Unified Legend



Internet service of Geological map information by the Geological Survey of Japan

URL: https://www.gsj.jp/en/index.html

Seamless geology

14 Aug. 2014 at Sakura-kan, Tsukuba

Thai-Myanmar harmonization

- ✓ How to solve discontinuities over cross border areas
  - Plan A: MoU for joint field survey
    - Require top level agreement
  - Plan B: CCOP organizes joint field survey
    - Require to extend ASEAN to CCOP
  - Plan C: Site visit by mutual invitation from department level
    - No fund in Myanmar
- ✓ Action plans
  - Myint Soe applies satellite images
  - Takahashi tabulates legend of Thai-Myanmar-Unified
  - Sompob reports progress to DMR Deputy D/G
  - Takahashi discuss CCOP seamless with Adichat in Sept.

Schedule related

Early Sept.	Okubo, Takahashi visit Myanmar
Early Sept.	Head delegate of DMR visits GSJ
Late Sept.	Takahashi visits DMR
Mid Oct.	CCOP Annual Session
Mid Oct.	ASOMM+3

Appendix 4

Groundwater

Groundwater Analysis Using Subsurface Temperature

Youhei UCHIDA

Geological Survey of Japan, AIST

Important key words

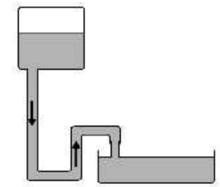
Potential energy is energy stored in a system of forcefully interacting physical entities.

Hydraulic head is equal to the fluid ‘s energy per unit weight. There are three types of head used to calculate the total head;

a. Velocity head is due to the bulk motion of a fluid (kinetic energy).
b. Elevation head is due to the fluid's weight, the gravitational force acting on a column of fluid.
c. Pressure head is due to the static pressure, the internal molecular motion of a fluid that exerts a force on its container.

Water table is defined as boundary between unsaturated and saturated zone. Groundwater in saturated zone moves according to hydraulic head.

Water level is a surface of water in a well or piezometer.

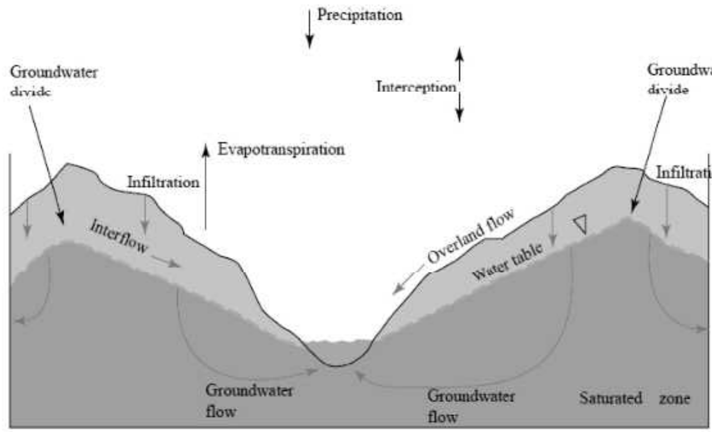


Fluid flows from the tank at the top to the basin at the bottom according to the hydraulic head.

AGENDA

1. Review : Basic Theory of Groundwater Flow System
2. Groundwater Flow System and Subsurface Thermal Regime
3. Exercise & Discussion: Analyze of Field Data
4. Excursion of GSHP System in Geological Museum

Water table and Groundwater flow



Three most important process that contribute to streamflow: overland flow, inter flow, and groundwater flow.

Water table is defined as boundary between unsaturated and saturated zone.

Topographic Driving Forces - Fluid Potential (1) -

***Fluid potential* (ϕ)**

“the mechanical energy per unit mass at any point in a flow system can be defined as the work required to move a unit mass of fluid from an arbitrarily chosen standard state to the point in question”

(Hubbert, 1940)

$$\phi = gz + \frac{v^2}{2} + \int_{p_0}^{p} \frac{dp}{\rho} \qquad (1)$$

g : G-forces, z : elevation, ρ : density,
v : velocity, p, p_0 : pressure at z and standard state, respectively

Topographic Driving Forces - Fluid Potential (2) -

For porous-media flow, velocities are extremely low, so Eq. (1) can be simplified further to give

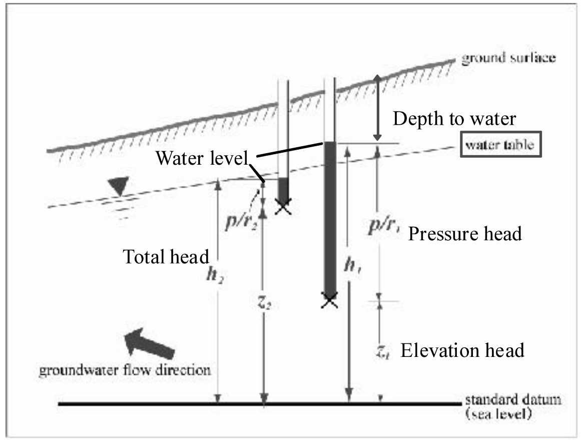
$$\phi = gz + \frac{p - p_0}{\rho} \qquad (2)$$

To set the atmospheric pressure p_0 equal to zero (standard state) and dividing through by g, we obtain

$$h = \frac{\phi}{g} = z + \frac{p}{r} \qquad (3)$$

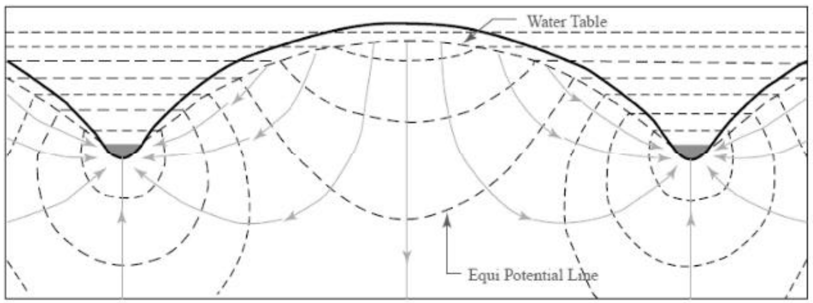
$r = \rho g$: specific weight

Topographic Driving Forces - Fluid Potential (3) -

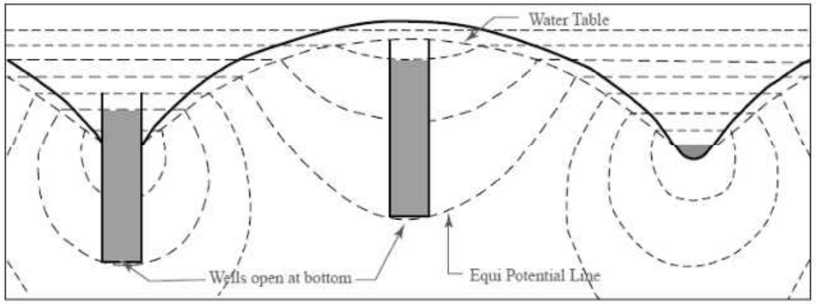


Schematic representation of the hydraulic potential

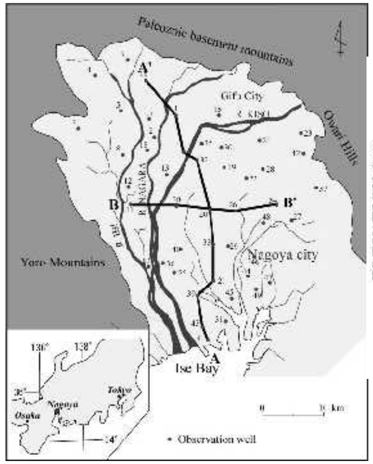
Water Table, Equi- Potential Line and Groundwater flow



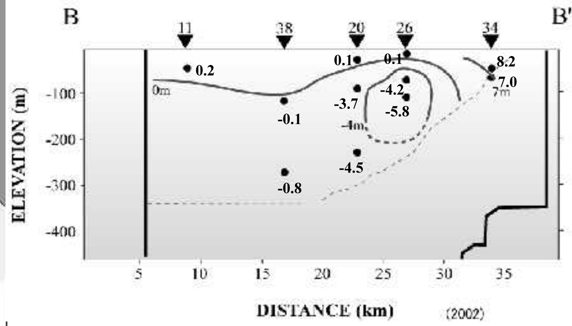
Water Table, Equi- Potential Line and Hydraulic Head



Example of Hydraulic Heads Distribution

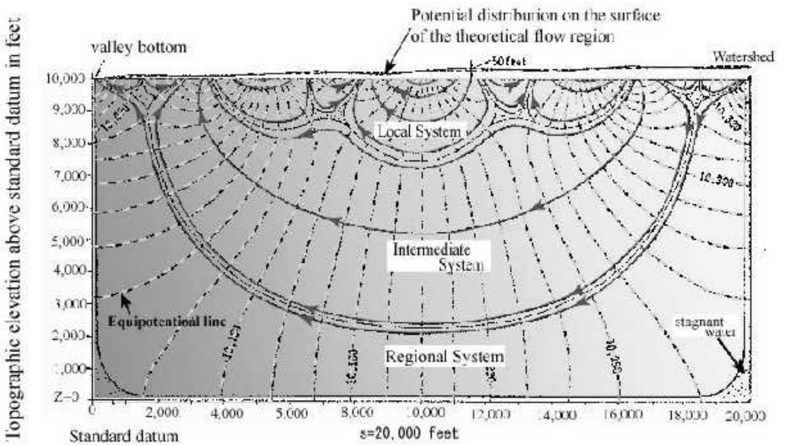


Study area and distribution of observation points



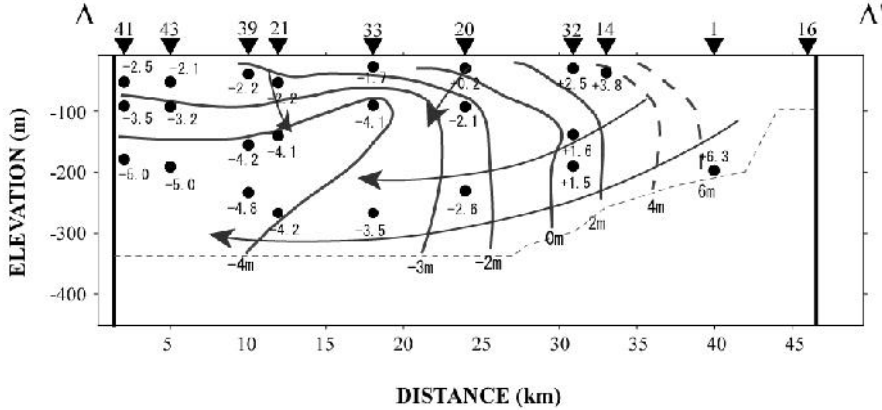
Distribution of hydraulic heads along the cross sections of B-B' line

Groundwater Flow System

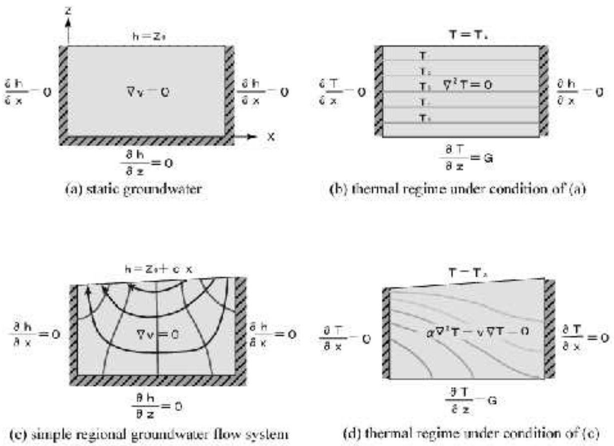


Equipotentioal line
Line of groundater flow (Toth, 1963)

Distribution of hydraulic heads along the cross sections of A-A' line



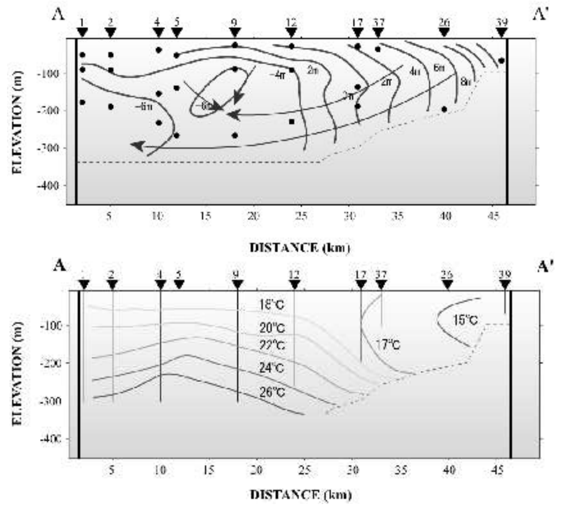
Groundwater Flow System and Subsurface Thermal Regime



h : hydraulic head,
v : groundwater flow velocity,
T : subsurface temperature,
Ts: constant surface temperature,
G : constant temperatrue gradient,
x,z : coordinate

(modified from Domenico and Palciauskas, 1973)

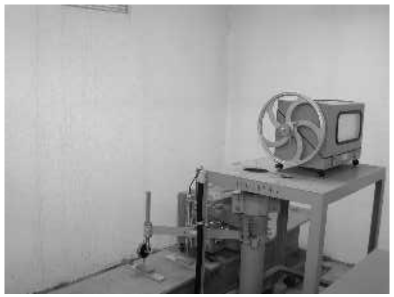
Subsurface thermal regime in Nobi Plain



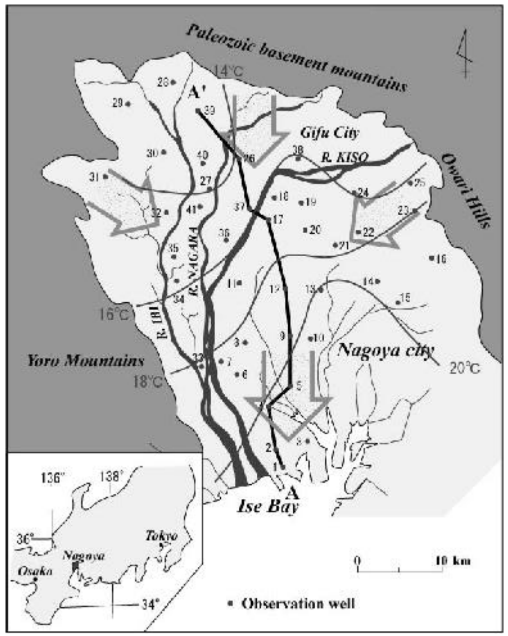
Equi-hydraulic potential line (upper) and isotherms (lower) along A-A' line （Uchida，1998）

Measuring Method of Subsurface Temperature

Thermometer
(Digital thermistor)



Observation well
(Monitoring for groundwater level and land subsidence)



Subsurface temperature distribution at -100m ASL in Nobi Plain （Uchida，1998）

Appendix 5

Geophysics

Compilation of Magnetic Anomaly Map of East Asia (& introduction to GMT software)

Takemi Ishihara
Institute of Geology & Geoinformation
Geological Survey of Japan, AIST

Data Sources

	Data Locality	Altitude	Year	Organization
C1	Eastern China	100-600	1979-83	AGS
C2	Yellow Sea, East China Sea, etc.	0	1970-83	MGIB1
C3	South China Sea	0	1971-87	MGIB2
I1	Offshore South Kalimantan	1500	1967	GRDC
I2	East Kalimantan	1200	1971	GRDC
I3	Java Island	750-1350	1973	GRDC
I4	Sunda Strait	150	1978	GRDC
I5	Makassar Strait	150	1978-79	GRDC
I6	South China Sea	0	1970-71	LEMIGAS
J1	Japanese Islands	3200	1964-83	GSJ & NEDO
J2	Izu Ogasawara Is., Japan Sea	0	1974-90	GSJ
J3	Philippine, East China & Japan Seas	0	1967-89	HDJ
K1	Taeback-Soebaek Mts & Gyeongsang	(150)	1958-59	KIGAM
K2	Gyeongsang	(40)	1975	KIGAM
K3	Jeju Island & Southern Korea	(120-300)	1982-89	KIGAM
M1	Peninsular Malaysia	(150)	1956-57	GSM
M2	Peninsular Malysia Central Belt	(120)	1980	GSM
M3	South China Sea	450	1965	PETRONAS
M4	Malay Basin	300	1969	PETRONAS
M5	Strait of Malacca	0	1972	PETRONAS
P1	Philippine Islands	1050-3150	1983	OEA
P2	Northeastern Luzon	2000	1977	MGB
P3	Palawan Island	0	1980	MGB
T1	Thailand	300-2250	1979-85	DMR
V1	Northern Vietnam	300-2200	1961-63	GDGV
V2	Offshore Vietnam	0	1983-85	GDOGV
G1	South China Sea & Sulu Sea	0	1977-87	BGR
R1	Japan Sea	0	1987-90	POI
R2	Offshore Vietnam	0	1982-90	POI
U1	Southern Vietnam	2000	1967	USNOO
U2	Taiwan Strait	150	1968	USNOO
U3	Palawan Island Continental Shelf	300	1969	USNOO
U4	Korean Continental Shelf	180	1969	USNOO
U5	Andaman Sea	150	1983	USNOO
U6	Sulu Archipelago	150	1984	USNOO
U7	Sulu Sea	150	1987	USNOO
X1	Various offshore areas	0	1960-88	NGDC
X2	Primorye	?	1949-62	NGDC

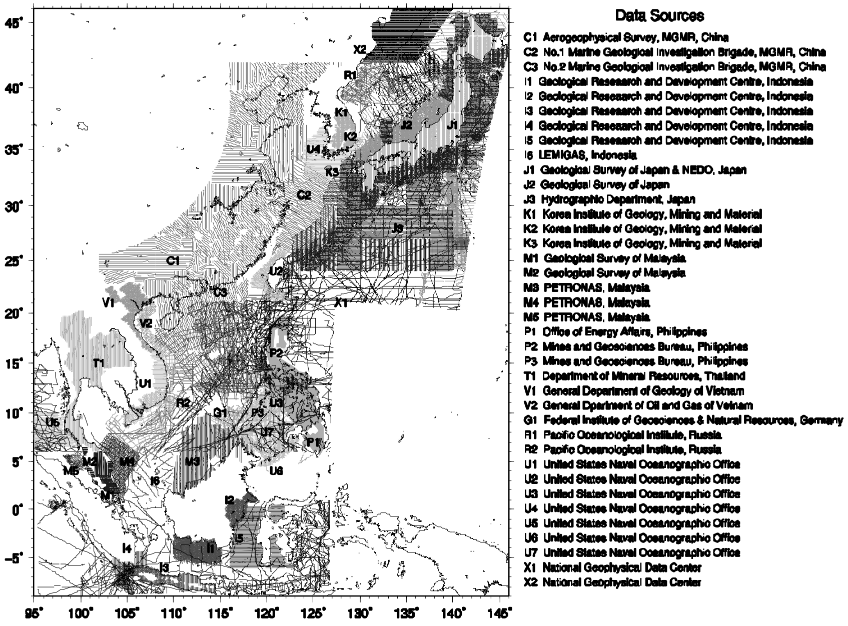
Abbreviations

AGS	Aerogeophysical Survey, MGMR, China
MGIB1	No.1 Marine Geological Investigation Brigade, MGMR, China
MGIB2	No.2 Marine Geological Investigation Brigade, MGMR, China
GRDC	Geological Research and Development Centre, Indonesia
LEMIGAS	LEMIGAS, Indonesia
GSJ	Geological Survey of Japan
NEDO	New Energy and Industrial Technology Development Organization, Japan
HDJ	Hydrographic Department of Japan
KIGAM	Korea Institute of Geology, Mining and Materials
GSM	Geological Survey of Malaysia
PETRONAS	PETRONAS, Malaysia
OEA	Office of Energy Affairs, Philippines
MGB	Mines and Geosciences Bureau, Philippines
DMR	Department of Mineral Resources, Thailand
GDGV	General Department of Geology of Vietnam
GDOGV	General Department of Oil and Gas of Vietnam
BGR	Federal Institute of Geosciences and Natural Resources, Germany
POI	Pacific Oceanological Institute, Russia

Aeromagnetic Map Compilation Programme (1987 – 1990)

- CCOP (Coordinating Committee for Coastal and Offshore Geoscience Programmes in East and Southeast Asia)
- The programme consists of training of magnetic data digitization, digital data modeling, etc. using PCs, and compilation of regional magnetic data.
- Publications of the programme:
  - Magnetic Anomaly Map of East Asia, 1:4,000,000 (1994)
  - Magnetic Anomaly Map of East Asia, 1:4,000,000 CD-ROM Version (1st Edition) (1996)
  - Magnetic Anomaly Map of East Asia, 1:4,000,000 CD-ROM Version (2nd Edition) (2002)

Data Distribution



Analog data used in compilation of Magnetic Anomaly Map of East Asia

Data set	Altitude(m)	Year	Line spacing	Scale	Contour Interval	Mag Field†
C1	100-600	1979-83	20 km	1:2,000,000	Profiles††	
C2	0	1970-83	20 km	1:2,000,000	Profiles††	
C3	0	1971-87	20 km	1:2,000,000	Profiles††	
I1	1500	1967	5 km	1:500,000	10 nT	Res.
I2	1200	1971	4 km	1:500,000	1-5 nT	Res.
I3	750-1350	1973	5 km	1:250,000	1-5 nT	Res.
I4*	150	1978	2 km	1:500,000	10 nT	Res.
I5*	150	1978-79	2 km	1:500,000	50 nT	Res.
I6	0	1970-71	50 km	1:1,000,000	25 nT	Tot.
K1	(150)	1958-59	1.6 km	1:100,000	10 nT	Res.
K2	(40)	1975	0.5 km	1:50,000	50 nT	Tot.
K3	(120-300)	1982-89	1 km	1:50,000	10 nT	Tot.
M1	(150)	1956-57	1 km	1:63,360	5-10 nT	Res.
M3	450	1965	10 km	1:1,000,000	10 nT	Res.
M4	300	1969	10 km	1:1,000,000	10 nT	Res.
M5	0	1972	10 km	1:1,000,000	10 nT	Res.
P1**	1050-3150	1983	2 km	1:250,000	1-5 nT	Tot.
P2**	2000	1977	1.5 km	1:250,000	5 nT	Res.
P3	?	1980	5 km	1:250,000	10 nT	Tot.
T1*	300-2250	1979-85	1 km	1:1,000,000	4-50 nT	Res.
V1*	300-2200	1961-63	2 km	1:500,000	25 nT	Res.
V2	0	1983-85	15-50 km	1:500,000	Profiles††	
U1	2000	1967	7 km	1:1,000,000	10 nT	Tot.
U2	150	1968	5 km	1:250,000	20 nT	Tot.
U3	300	1969	7 km	1:250,000	20 nT	Tot.
U4	180	1969	7 km	1:250,000	50 nT	Tot.

*Data sets I4, I5, T1 and V1 were digitized using assumed flight lines.
**Data sets P1 and P2 are created by reading grid values from contour maps. Data set P1 is not included in MAMEA CD-ROM.
†Mag field means type of magnetic field shown in the map, i.e., total field or residual value.
††Data sets C1, C2, C3 and V2 were digitized using profile maps, i.e., maps with magnetic anomaly profiles along track lines (or flight lines).

Digitization
with a PC and a digitizer
180 magnetic maps

CCOP Newsletter Vol. 13, No. 4, October 1 to December 3

DIGITIZING AND GRIDDIN
USIN

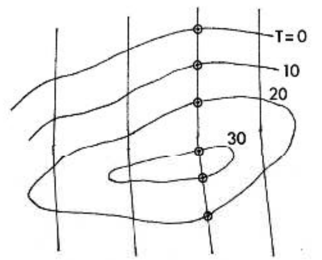
Takemi ISHIHARA and

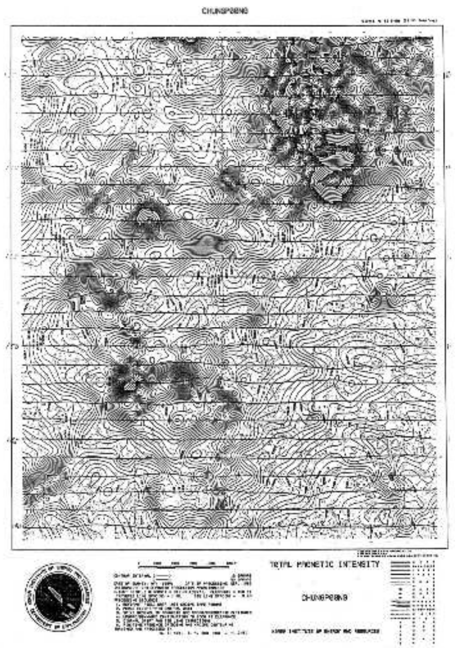
Introduction

Contour map

- Digitization of intersections between contours and track lines (flight lines)
- Conversion from (X, Y) to (lat., long.)
- Anomaly calculation using reference DGRF as a function of (lat., long., date (year, month, day))
  - A = Tobs - Tref
  - (= Tobs - T avr, if only relative values are known)
- Data interpolation at constant interval of 0.5 to 2 km
  - Akima's cubic spline method

Profile data set

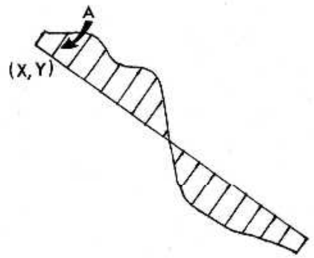


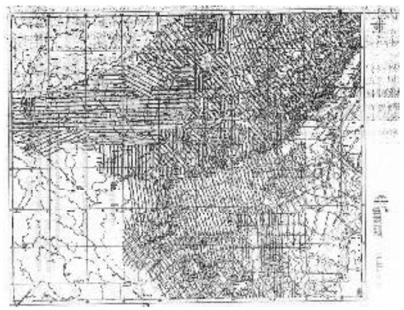


Profile map

- Digitization of profiles at a constant interval of 0.5 to 2 km along track lines (flight lines)
- Conversion from (X, Y) to (lat., long.)

Profile data set





Profile data sets

Bias correction to each data set

(All profile data sets combined)

Cross over analysis

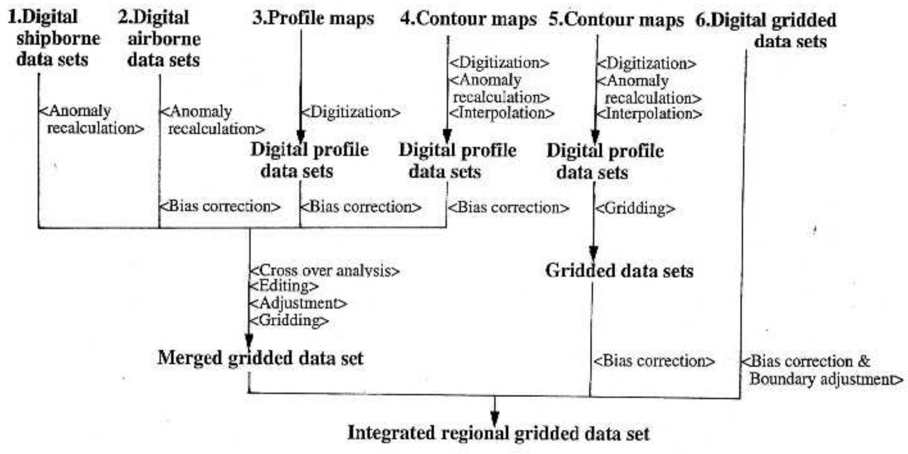
Editing
Removal of bad data segments

Adjustment
Corrections using Akima's cubic spline functions of time

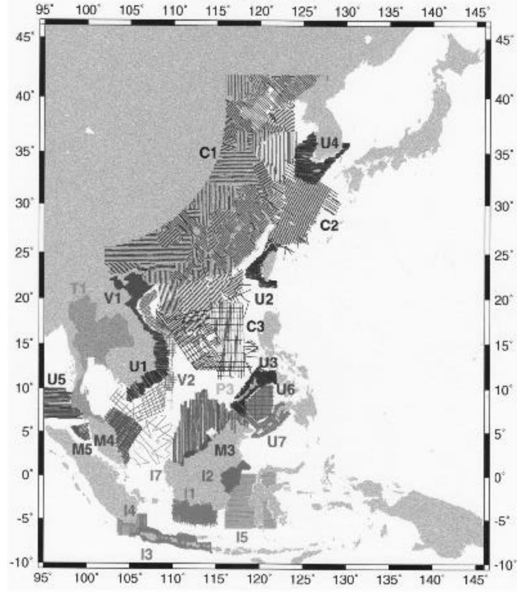
Gridding
Average with weight aproximately proportional to $(\text{distance})^{-4}$

Merged gridded data set

Summary of data processing for compilation of Magnetic Anomaly Map of East Asia



Merged data



Corrections for merged data sets

Data set	Correction applied (nT)
C1, C2, C3	-80
U2	0
U4	-80
I1	-150
I2	?
I3	?
I4	-55
I5	-183
I6	+155
M3	-30
M4	-100
M5	+126
P3	-20
T1	-20
V1	-25
V2	+10
U1	0
U3	-20
U5	0
U6	+10
U7	+15

Original data used in compilation of Magnetic Anomaly Map of East Asia

1. Digital shipborne data sets used as reference
J2, J3, G1, R1, R2, X1

2. Merged digital airborne data sets (line spacing)
U5 (12 km), U6 (10 km), U7 (12 km)

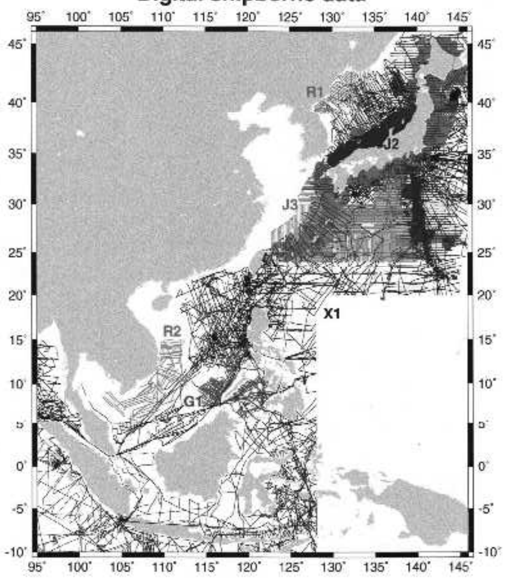
Data set	Line spacing	Scale	Map size	No of sheets
3. Profile maps				
C1, C2, C3	20 km	1:2,000,000	75 cm x 90 cm	x 6
V2	15-50 km	1:500,000	120 cm x 85 cm	x 6
4. Contour maps				
I1	5 km	1:500,000	120 cm x 70 cm	x 1
I2	4 km	1:500,000	80 cm x 85 cm	x 1
I3	5 km	1:250,000	70 cm x 50 cm	x 15
I4*	2 km	1:500,000	70 cm x 60 cm	x 1
I5*	2 km	1:500,000	120 cm x 130 cm	x 1
I6	50 km	1:1,000,000	60 cm x 70 cm	x 1
M3	10 km	1:1,000,000	105 cm x 100 cm	x 1
M4	10 km	1:1,000,000	50 cm x 70 cm	x 1
M5	10 km	1:1,000,000	120 cm x 130 cm	x 1
P3	5 km	1:250,000	75 cm x 70 cm	x 2
T1*	1 km	1:1,000,000	80 cm x 80 cm	x 2
V1*	2 km	1:500,000	60 cm x 70 cm	x 4
U1	7 km	1:1,000,000	45 cm x 100 cm	x 1
U2	5 km	1:250,000	90 cm 70 cm	x 4
U3	7 km	1:250,000	80 cm x 110 cm	x 7
U4	7 km	1:250,000	80 cm x 100 cm	x 9
5. Contour maps (separately gridded)				
K1	1.6 km	1:100,000	130 cm x 95 cm	x 8
K2	0.5 km	1:50,000	50 cm x 40 cm	x 11
K3	1 km	1:50,000	50 cm x 40 cm	x 15
M1	1 km	[illegible]	[illegible]	[illegible]
P1**	2 km	1:250,000	65 cm x 45 cm	x 37
P2**	1.5 km	1:250,000	70 cm x 60 cm	x 1

6. Digital grid data sets (original grid interval)
J1 (0.5' x 0.5'), M2 (0.6 km x 0.6 km), X2 (1' x 1')

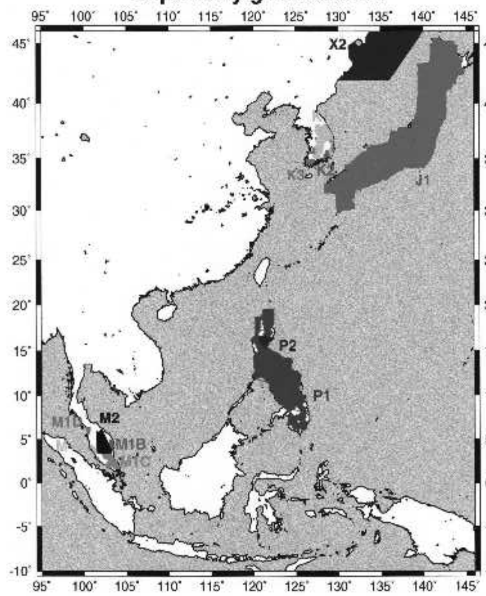
Total number of digitized sheets: 180

*Data sets I4, I5, T1 and V1 were digitized using assumed flight lines.
**Data sets P1 and P2 are created by reading grid values from contour maps. Data set P1 is not included in MAMEA CD-ROM.

Digital shipborne data



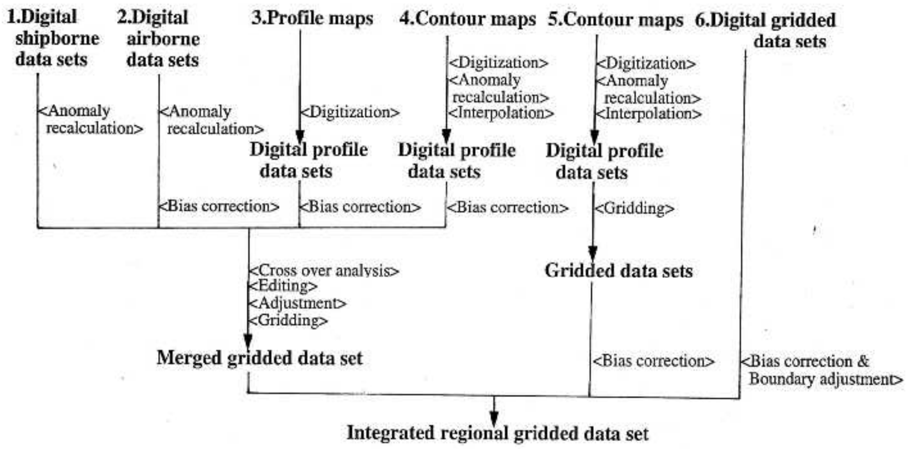
Separately gridded data



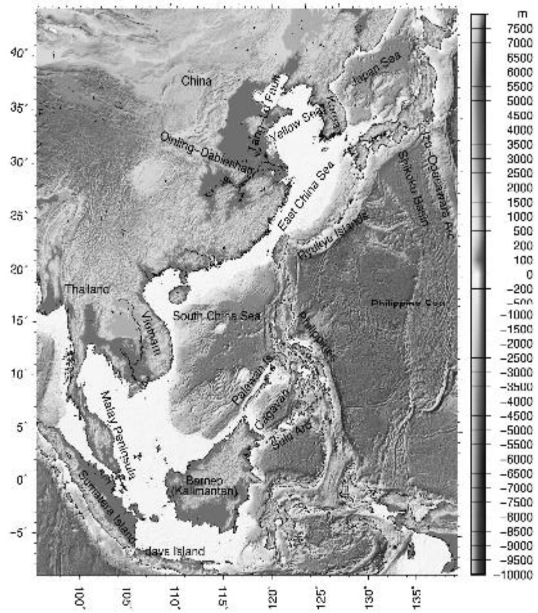
Corrections for separately gridded data sets

Data set	Correction applied (nT, nT/km, nT/km)
K1	+150 + 0.5(x-xo)-1.0(y-yo)
	(xo, yo): (37 N, 128 E)
K2	-100
K3	0
J1	+ 0.2 $(x-x_0)$ - 0.2 (y-yo)
	(xo,yo): (36N,135E)
X2	0
M1A	-150
M1B	+250
M1C	+200 - 0.5 (x-xo) - 2.0 (y-yo)
	(xo, yo): (3 N, 103 E)
M1D	+300
M2	+75
P1	-50
P2	+20

Summary of data processing for compilation of Magnetic Anomaly Map of East Asia



Topographic map of East Asia



Geological implications of magnetic anomalies:

1) Lineated anomalies due to seafloor spreading

2) Anomalies associated with volcanoes, volcanic islands & seamounts along island arcs

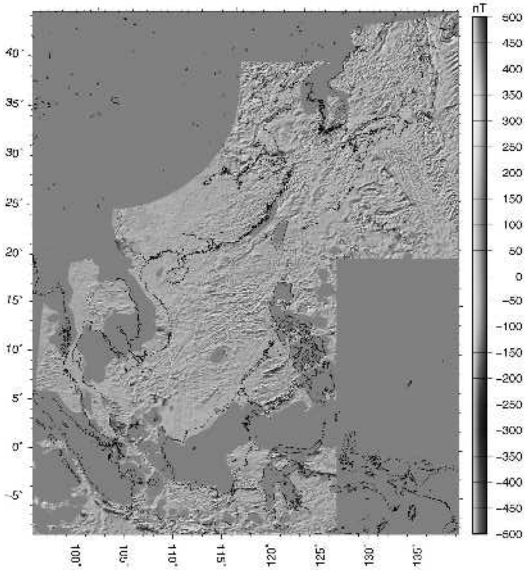
3) Fault systems

4) Igneous & metamorphic rocks of ophiolite belts, etc.

5) Granitic plutons

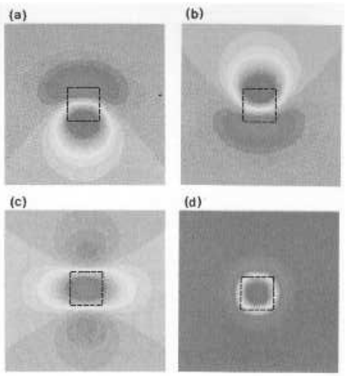
6) Thick sedimentary basin – long wavelength features without conspicuous anomalies

Magnetic Anomaly Map of East Asia

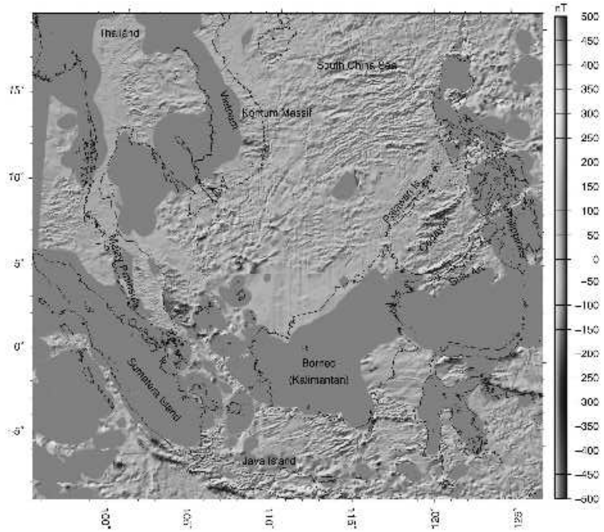


Magnetic anomaly patterns due to a cubic source body

a) middle latitude - northern hemisphere
b) middle latitude - southern hemisphere
c) magnetic equator
d) magnetic north and south poles



Lower half (Philippines, Vietnam, Thailand, Malaysia and Indonesia)



Geological implications:

1) Lineated anomalies due to seafloor spreading

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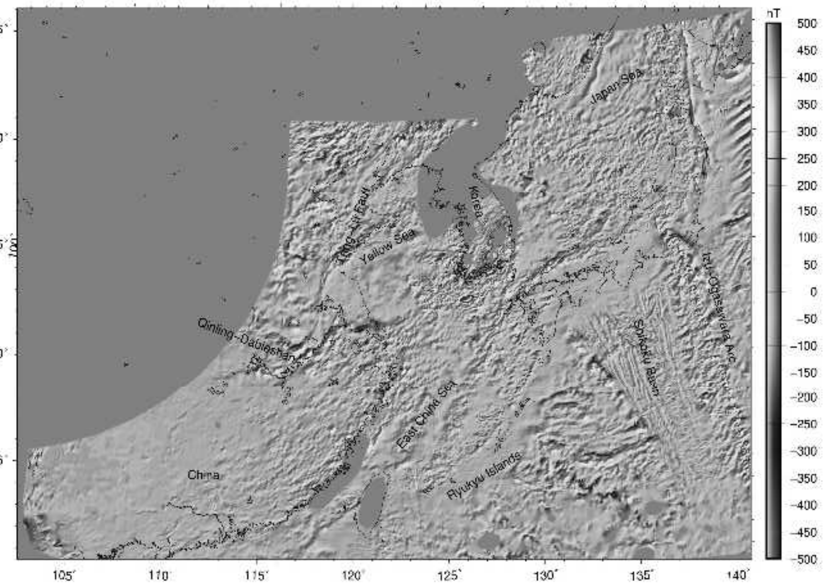
3) Fault systems

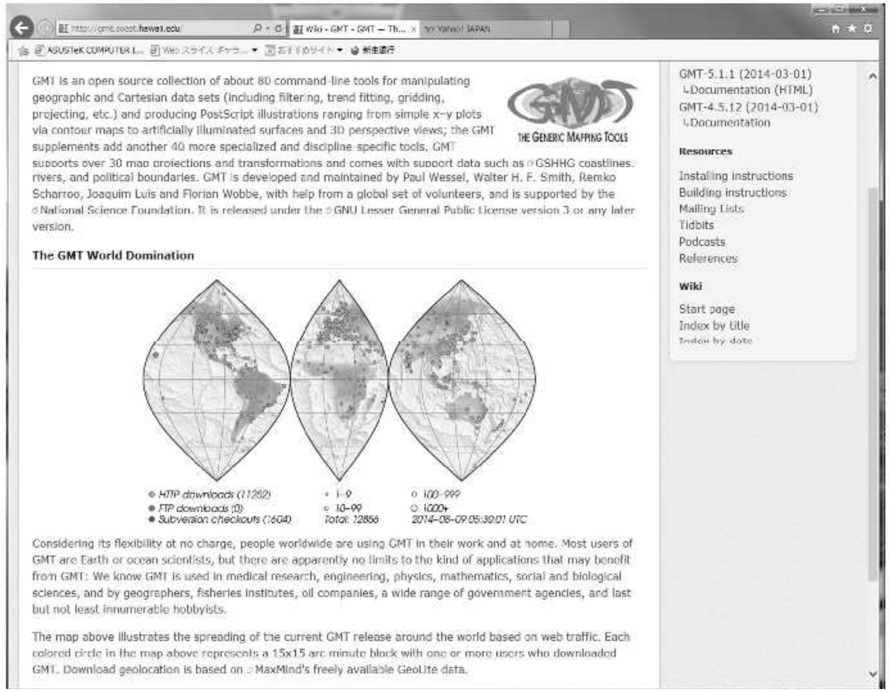
4) Igneous & metamorphic rocks of ophiolite belts, etc.

5) Granitic plutons

6) Thick sedimentary basin – long wavelength features without conspicuous anomalies

Upper half (Eastern China, Korea and Japan)





GMT

- The Generic Mapping Tools, GMT, are an open source collection of tools for manipulating geographic and Cartesian data sets (including filtering, trend fitting, gridding, projecting, etc.) and producing PostScript illustrations ranging from simple x–y plots via contour maps to artificially illuminated surfaces and 3D perspective views. It is released under the GNU Lesser General Public License.
- The software can be downloaded from the web site:
  http://gmt.soest.hawaii.edu/
- 1-min grid topographic data can be downloaded from SIO web site:
  http://topex.ucsd.edu/marine_topo/

GMT programs

	Filtering of 1-D and 2-D Data
blockmean	L_2 (x,y,z) table data filter/decimator
blockmedian	L_1 (x,y,z) table data filter/decimator
blockmode	Mode estimate (x,y,z) table data filter/decimator
filter1d	Filter 1-D table data sets (time series)
grdfilter	Filter 2-D gridded data sets in the space domain
	Plotting of 1-D and 2-D Data
grdcontour	Contouring of 2-D gridded data sets
grdimage	Produce images from 2-D gridded data sets
grdvector	Plotting of 2-D gridded vector fields
grdview	3-D perspective imaging of 2-D gridded data sets
psbasemap	Create a basemap plot
psclip	Use polygon files to define clipping paths
pscoast	Plot (and fill) coastlines, borders, and rivers on maps
pscontour	Contour or image raw table data by triangulation
pshistogram	Plot a histogram
psimage	Plot Sun raster files on a map
pslegend	Plot a legend on a map
psmask	Create overlay to mask out regions on maps
psrose	Plot sector or rose diagrams
psscale	Plot gray scale or color scale on maps
pstext	Plot text strings on maps
pswiggle	Draw table data time-series along track on maps
psxy	Plot symbols, polygons, and lines on maps
psxyz	Plot symbols, polygons, and lines in 3-D
	Gridding of Data Tables
greenspline	Interpolation with Green's functions for splines in 1–3 D
nearneighbor	Nearest-neighbor gridding scheme
sphinterpolate	Spherical gridding in tension of data on a sphere
surface	A continuous curvature gridding algorithm
triangulate	Perform optimal Delauney triangulation and gridding
	Sampling of 1-D and 2-D Data
gmtsimplify	Line reduction using the Douglas-Peucker algorithm
grdsample	Resample a 2-D gridded data set onto a new grid
grdtrack	Sampling of 2-D gridded data set(s) along 1-D track
sample1d	Resampling of 1-D table data sets
	Projection and Map-transformation
grdproject	Project gridded data sets onto a new coordinate system
mapproject	Transformation of coordinate systems for table data
project	Project table data onto lines or great circles
	Retrieve Information
gmtdefaults	List the current default settings
gmtget	Retrieve selected parameters in current file
gmtinfo	Get information about table data files

gmtset	Change selected parameters in current file
grdinfo	Get information about grid files
	Mathematical Operations on Tables or Grids
gmtmath	Mathematical operations on table data
makecpt	Make color palette tables
spectrum1d	Compute various spectral estimates from time-series
sph2grd	Compute grid from spherical harmonic coefficients
sphdistance	Make grid of distances to nearest points on a sphere
sphtriangulate	Delaunay or Voronoi construction of spherical lon,lat data
	Convert or Extract Subsets of Data
gmtconnect	Connect segments into more complete lines or polygons
gmtconvert	Convert data tables from one format to another
gmtselect	Select subsets of table data based on multiple spatial criteria
gmtspatial	Geospatial operations on lines and polygons
gmtvector	Basic operations on vectors in 2-D and 3-D
grd2rgb	Convert Sun raster or grid file to red, green, blue component grids
grd2xyz	Conversion from 2-D grid file to table data
grdblend	Blend several partially over-lapping grid files onto one grid
grdcut	Cut a sub-region from a grid file
grdpaste	Paste together grid files along a common edge
grdreformat	Converts grid files into other grid formats
splitxyz	Split xyz files into several segments
xyz2grd	Convert an equidistant table xyz file to a 2-D grid file
	Determine Trends in 1-D and 2-D Data
fitcircle	Finds the best-fitting great or small circle for a set of points
grdtrack	Sampling of 2-D gridded data set(s) along 1-D track
trend1d	Fits polynomial or Fourier trends to $y = f(x)$ series
trend2d	Fits polynomial trends to $z = f(x, y)$ series
	Other Operations on 2-D Grids
grd2cpt	Make color palette table from a grid files
grdclip	Limit the z-range in gridded data sets
grdedit	Modify header information in a 2-D grid file
grdfft	Perform operations on grid files in the frequency domain
grdgradient	Compute directional gradient from grid files
grdhisteq	Histogram equalization for grid files
grdlandmask	Create masking grid files from shoreline data base
grdmask	Reset grid nodes in/outside a clip path to constants
grdmath	Mathematical operations on grid files
grdvolume	Calculate volumes under a surface within specified contour
	Miscellaneous Tools
gmt2kml	Like psxy but plots KML for use in Google Earth
kml2gmt	Extracts coordinates from Google Earth KML files
ps2raster	Crop and convert PostScript files to raster images, EPS, and PDF

Projections in GMT

WITH GMT PROJECTION CODES	
-J (upper case for *width*, lower case for *scale*) Map projection	
-JAlon$_0$/lat$_0$[/*horizon*]/*width*	Lambert azimuthal equal area
-JBlon$_0$/lat$_0$/lat$_1$/lat$_2$*width*	Albers conic equal area
-JClon$_0$/lat$_0$*width*	Cassini cylindrical
-JCyl_stere/[lon$_0$[/lat$_0$/]]*width*	Cylindrical stereographic
-JDlon$_0$/lat$_0$/lat$_1$/lat$_2$*width*	Equidistant conic
-JElon$_0$/lat$_0$[/*horizon*]/*width*	Azimuthal equidistant
-JFlon$_0$/lat$_0$[/*horizon*]/*width*	Azimuthal gnomonic
-JGlon$_0$/lat$_0$[/*horizon*]/*width*	Azimuthal orthographic
-JGlon$_0$/lat$_0$*alt*/*azim*/*tilt*/*twist*/*W*/*H*/*width*	General perspective
-JHlon$_0$*width*	Hammer equal area
-JIlon$_0$*width*	Sinusoidal equal area
-JJlon$_0$*width*	Miller cylindrical
-JKflon$_0$*width*	Eckert IV equal area
-JKslon$_0$*width*	Eckert VI equal area
-JLlon$_0$/lat$_0$/lat$_1$/lat$_2$*width*	Lambert conic conformal
-JM[lon$_0$[/lat$_0$/]]*width*	Mercator cylindrical
-JN[lon$_0$/]*width*	Robinson
-JOalon$_0$/lat$_0$*azim*/*width*	Oblique Mercator, 1: origin and azimuth
-JOblon$_0$/lat$_0$/lon$_1$/lat$_1$*width*	Oblique Mercator, 2: two points
-JOclon$_0$/lat$_0$/lon$_p$/lat$_p$*width*	Oblique Mercator, 3: origin and pole
-JP[a]*width*[/*origin*]	Polar [azimuthal] (θ, r) (or cylindrical)
-JPoly[lon$_0$[/lat$_0$/]]*width*	(American) polyconic
-JQ[lon$_0$[/lat$_0$/]]*width*	Equidistant cylindrical
-JR[lon$_0$/]*width*	Winkel Tripel
-JSlon$_0$/lat$_0$[/*horizon*]/*width*	General stereographic
-JT[lon$_0$[/lat$_0$/]]*width*	Transverse Mercator
-JU*zone*/*width*	Universal Transverse Mercator (UTM)
-JV[lon$_0$/]*width*	Van der Grinten
-JW[lon$_0$/]*width*	Mollweide
-JX*width*[l|p*exp*|T|t][/*height*[l|p*exp*|T|t]][d]	Linear, $\log_{10}$, $x^a - y^b$, and time
-JYlon$_0$/lat$_0$*width*	Cylindrical equal area

WITH Proj4 PROJECTION CODES	
-J (lower case for *scale* only) Map projection	
-Jaea/lon$_0$/lat$_0$/lat$_1$/lat$_2$*scale*	Albers conic equal area
-Jaeqd/lon$_0$/lat$_0$[/*horizon*]/*scale*	Azimuthal equidistant
-Jcass/lon$_0$/lat$_0$*scale*	Cassini cylindrical
-Jcea/lon$_0$/lat$_0$*scale*	Cylindrical equal area
-Jcyl_stere/[lon$_0$[/lat$_0$/]]*scale*	Cylindrical stereographic
-Jeqc/[lon$_0$[/lat$_0$/]]*scale*	Equidistant cylindrical
-Jeqdc/lon$_0$/lat$_0$/lat$_1$/lat$_2$*scale*	Equidistant conic
-Jgnom/lon$_0$/lat$_0$[/*horizon*]/*scale*	Azimuthal gnomonic
-Jhammer/lon$_0$*scale*	Hammer equal area
-Jeck4/lon$_0$*scale*	Eckert IV equal area
-Jeck6/lon$_0$*scale*	Eckert VI equal area
-Jlaea/lon$_0$/lat$_0$[/*horizon*]/*scale*	Lambert azimuthal equal area
-Jlcc/lon$_0$/lat$_0$/lat$_1$/lat$_2$*scale*	Lambert conic conformal
-Jmerc/[lon$_0$[/lat$_0$/]]*scale*	Mercator cylindrical
-Jmill/lon$_0$*scale*	Miller cylindrical
-Jmoll/[lon$_0$/]*scale*	Mollweide
-Jnsper/lon$_0$/lat$_0$*alt*/*azim*/*tilt*/*twist*/*W*/*H*/*scale*	General perspective
-Jomerc/lon$_0$/lat$_0$*azim*/*scale*	Oblique Mercator, 1: origin and azimuth
-Jomerc/lon$_0$/lat$_0$/lon$_1$/lat$_1$*scale*	Oblique Mercator, 2: two points
-Jomercp/:lon$_0$/lat$_0$/lon$_p$/lat$_p$*scale*	Oblique Mercator, 3: origin and pole
-Jortho/lon$_0$/lat$_0$[/*horizon*]/*scale*	Azimuthal orthographic
-Jpolar/[a]*scale*[/*origin*]	Polar [azimuthal] (θ, r) (or cylindrical)
-Jpoly/[lon$_0$[/lat$_0$/]]*scale*	(American) polyconic
-Jrobin/[lon$_0$/]*scale*	Robinson
-Jsinu/lat$_0$*scale*	Sinusoidal equal area
-Jstere/lon$_0$/lat$_0$[/*horizon*]/*scale*	General stereographic
-Jtmerc/[lon$_0$[/lat$_0$/]]*scale*	Transverse Mercator
-Jutm/*zone*/*scale*	Universal Transverse Mercator (UTM)
-Jvandg/[lon$_0$/]*scale*	Van der Grinten
-Jwintri/[lon$_0$/]*scale*	Winkel Tripel
-Jxy*xscale*[l|p*exp*|T|t][/*yscale*[l|p*exp*|T|t]][d]	Linear, $\log_{10}$, $x^a - y^b$, and time

Built-in color palette tables

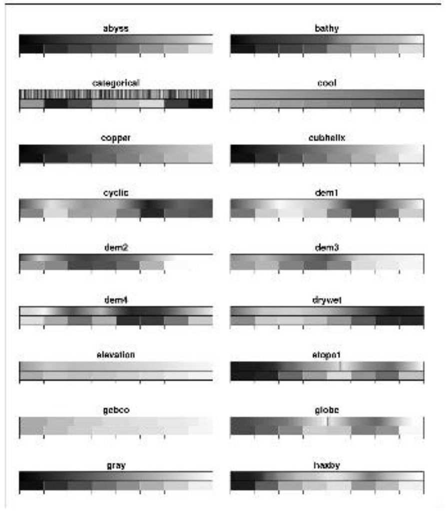


Figure 23.1: The first 18 of the standard 36 CPT files supported by GMT

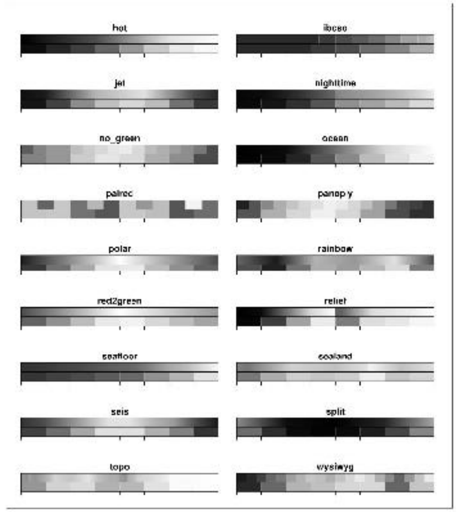


Figure 23.2: The second 18 of the standard 36 CPT files supported by GMT

STANDARDIZED COMMAND LINE OPTIONS	
-B*information*	Specify map frame and axes parameters
-K	Append more PS later
-O	This is an overlay plot
-P	Select Portrait orientation
-R*west*/*east*/*south*/*north*[/*zmin*/*zmax*][r]	Specify Region of interest
-U[[*just*]/*dx*/*dy*/][*label*]	Plot time-stamp on plot
-V	Run in verbose mode
-X[a| c| r]*off*[u]	Shift plot origin in *x*-direction
-Y[a| c| r]*off*[u]	Shift plot origin in *y*-direction
-a*name*=*col*,...	Associates aspatial data with columns
-b[i| o][*ncol*][t]	Select binary input or output
-c*copies*	Set number of plot copies [1]
-f[i| o]*colinfo*	Set formatting of ASCII input or output
-g[+]x| X| y| Y| d| D*gap*[u]	Segment data by detecting gaps
-h[i| o][*n_headers*]	ASCII [input| output] tables have header record[s]
-i*columns*	Selection of input columns
-o*columns*	Selection of output columns
-n[*type*][+a][+b*BC*] [+c][+t*threshold*]	Set grid interpolation mode
-p*azim*/*elev*[/*zlevel*][+w*lon0*/*lat0*[/*z0*]][+v*x0*/*y0*]	Control 3-D perspective view
-r	Sets grid registration
-s[z| *cols*]	Control treatment of NaN records
-t*transparency*	Set layer PDF transparency
-:[i| o]	Expect *y*/*x* input rather than *x*/*y*

Review of geodynamics and introduction of geothermics and Curie depth analysis

Yasukuni Okubo
Geological Survey of Japan / AIST

Workshop in Tsukuba 2014

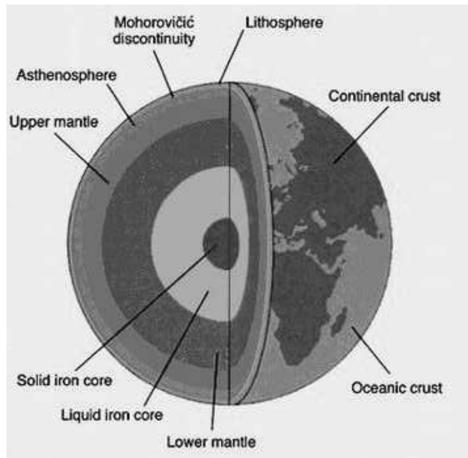
Home Works

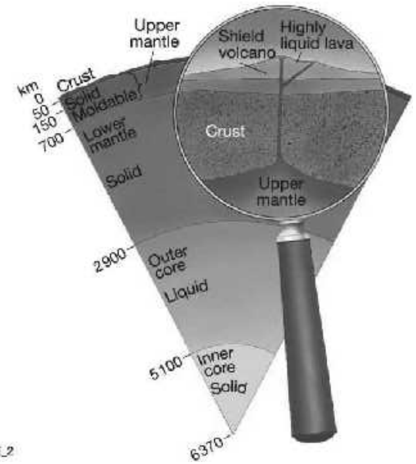
Illustrate a model of earth's thermal structure

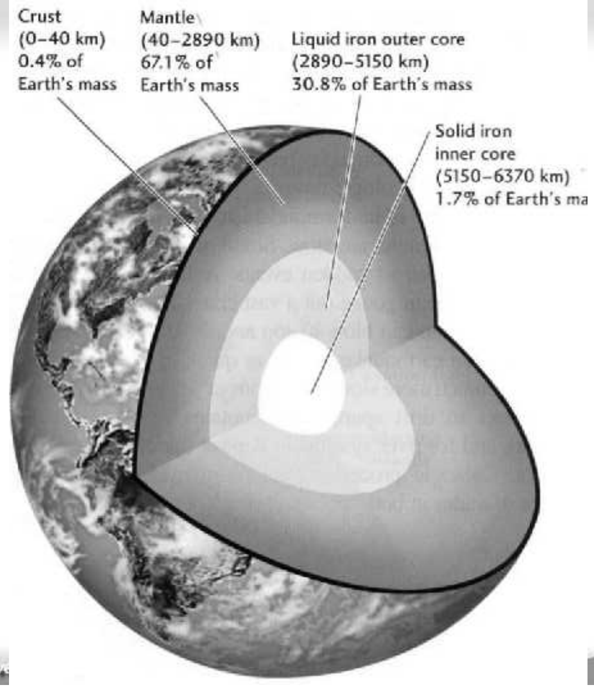
including key words of core, mantle, crust, ridge, Curie isotherm, magnetic isochrones, volcano, hot spring

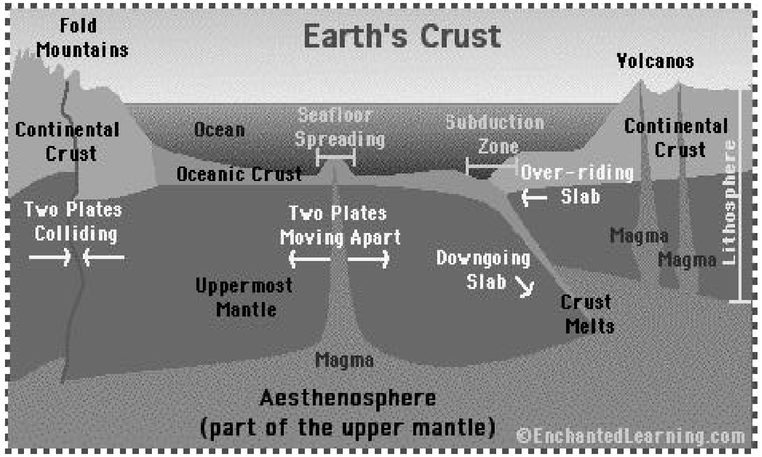
Review of Geodynamics

(2) Illustrate a mode of earth's thermal structure

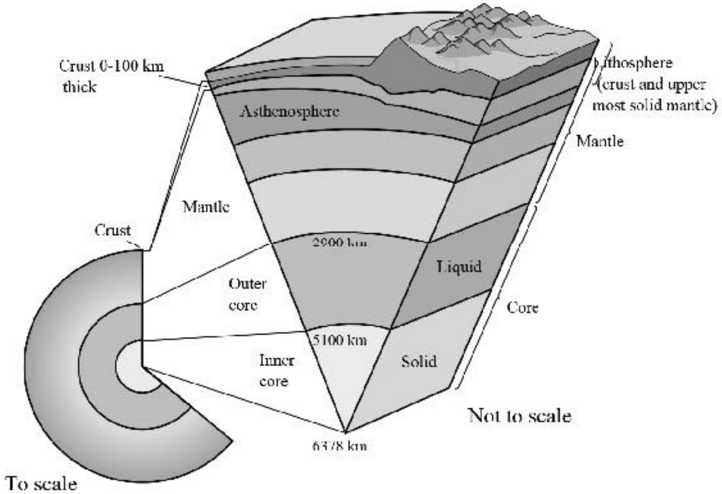








Schema of the cut-away Earth



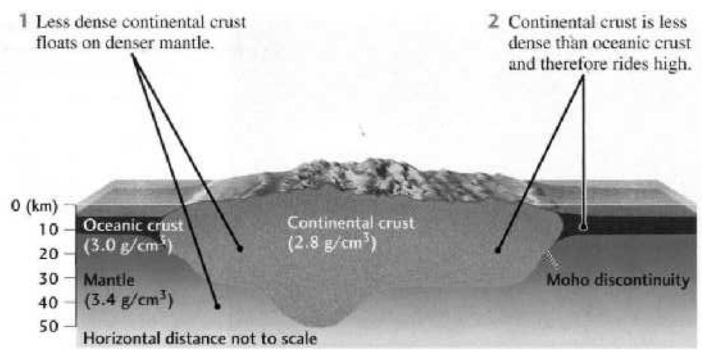
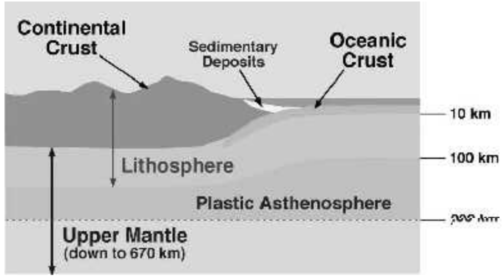
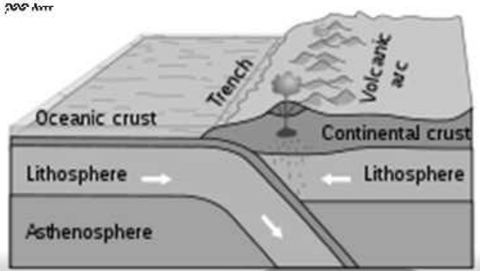


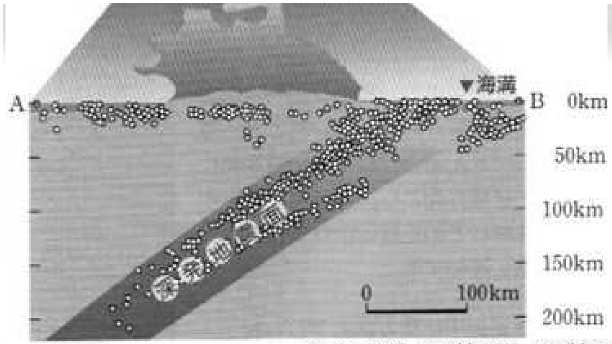
Figure 1.7 Continents float high because they are made of rocks with lower densities than rocks of the mantle or oceanic crust.

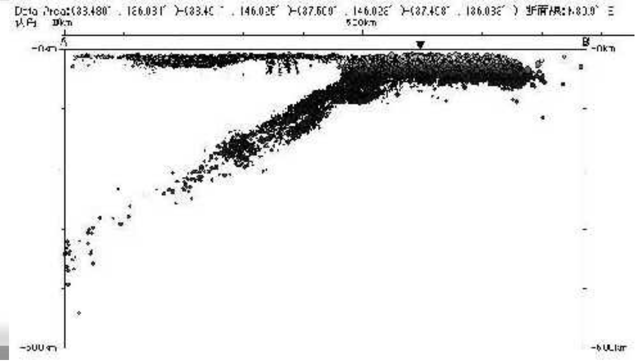
Continental drift





Geological Survey of Japan, AIST





Geological Survey of Japan, AIST

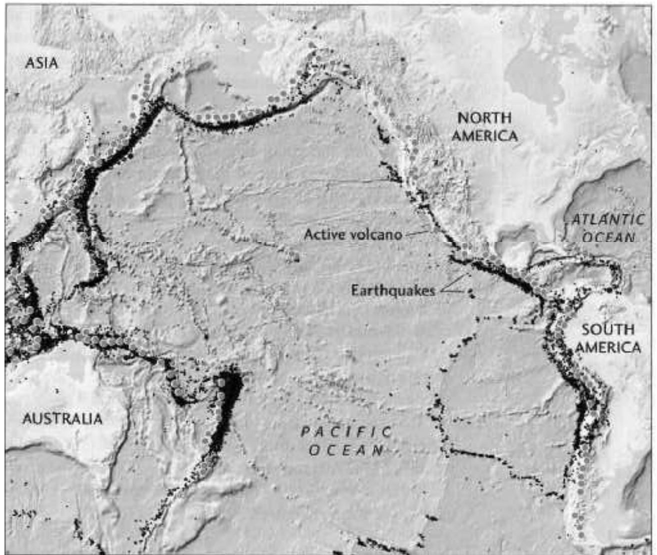
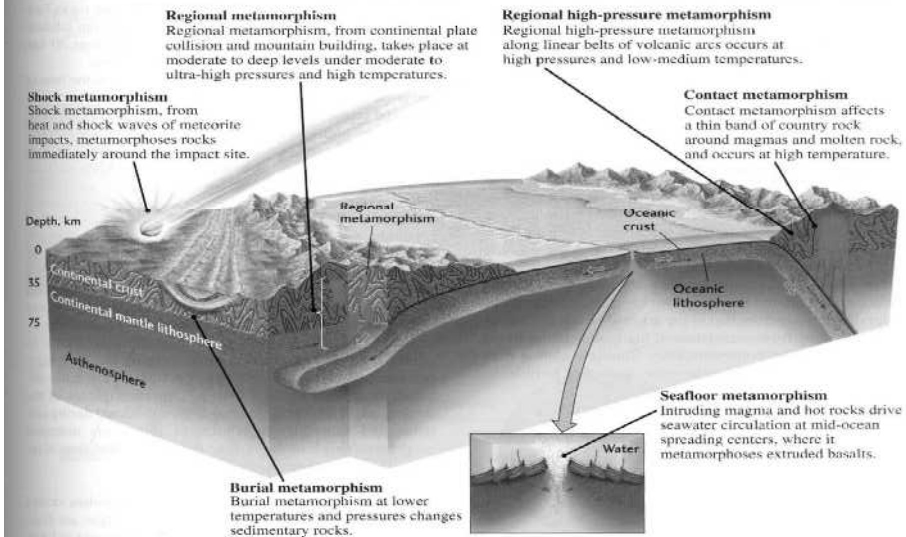
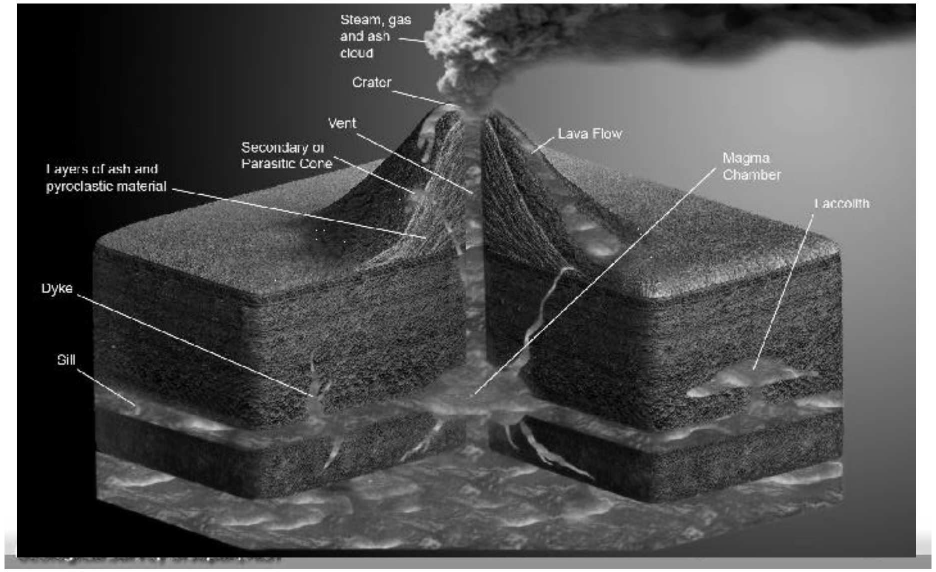


Figure 2.4 The Pacific Ring of Fire, showing active volcanoes (large red circles) and earthquakes (small black dots).

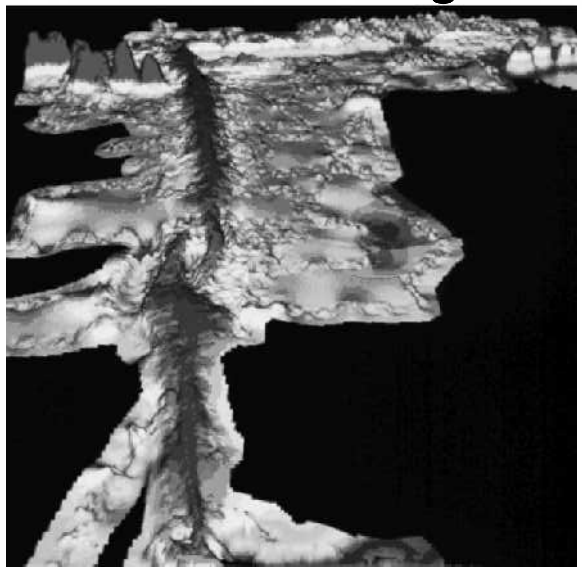
Earth System Figure 6.3 The lithosphere and asthenosphere interact to metamorphose rock.

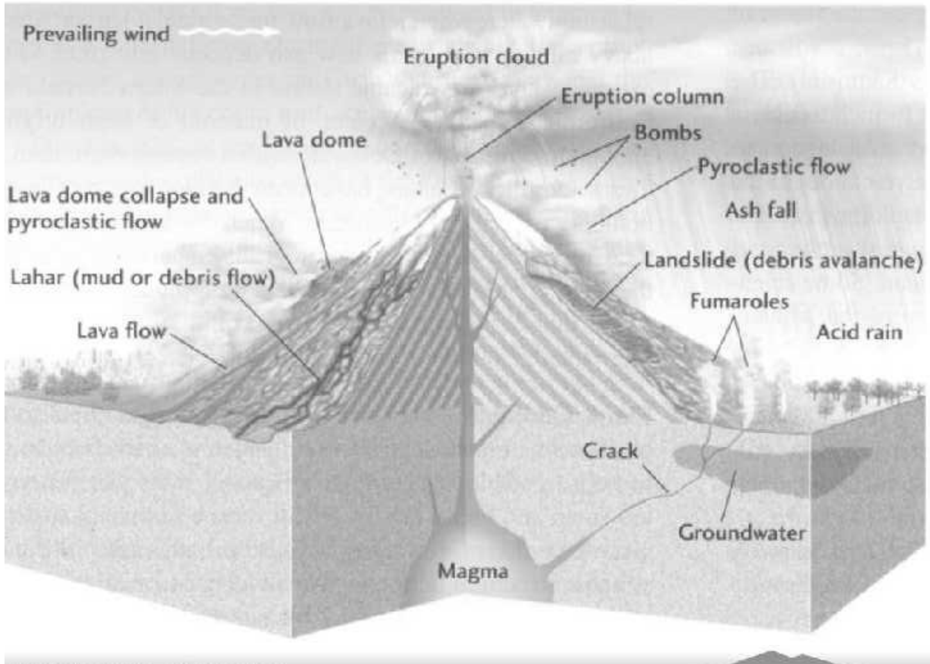


Volcano Activity

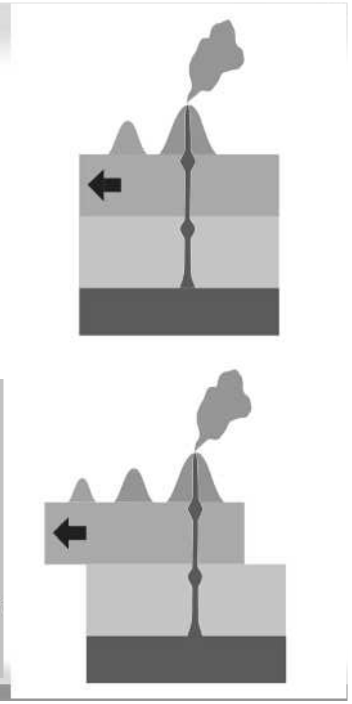


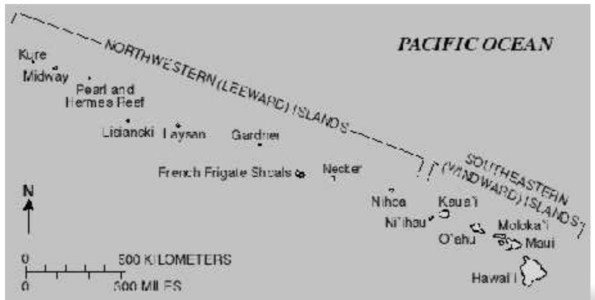
Mid-ocean ridge





Hot Spot





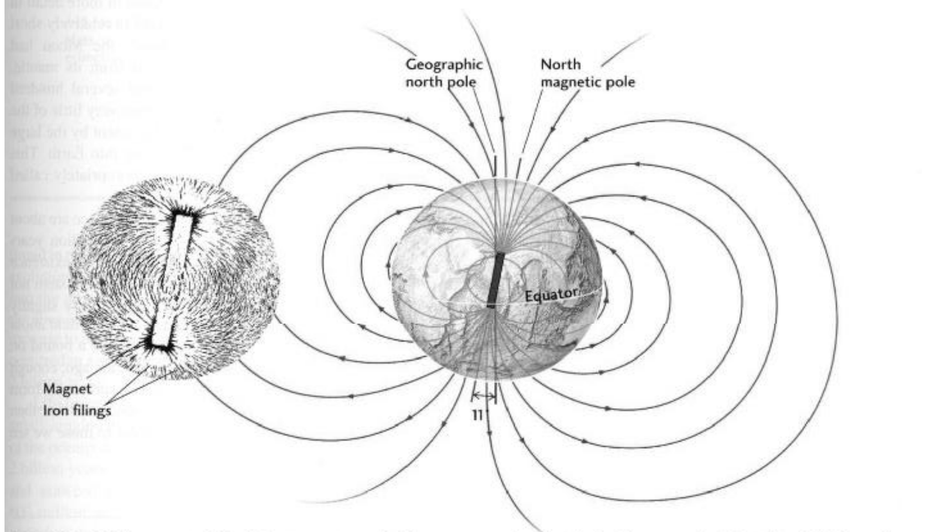
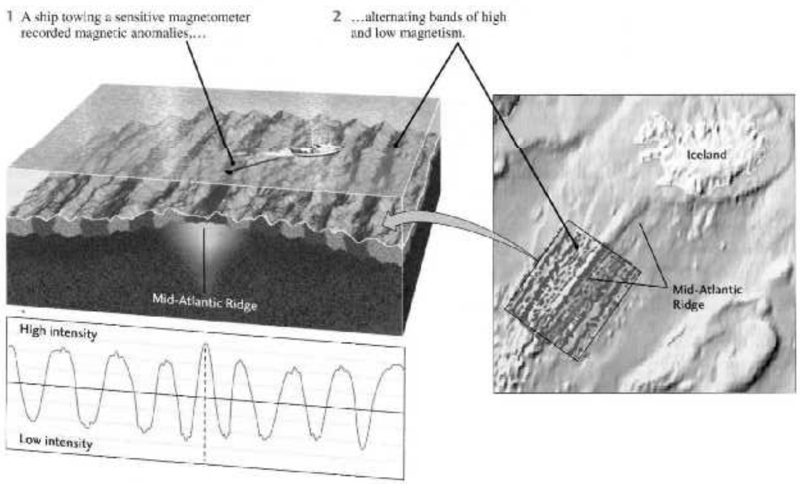


Figure 1.12 *(left)* The magnetic field of a bar magnet is revealed by the alignment of iron filings on paper. [After *PSSC Physics*, 3d ed. (Lexington, Mass.: D. C. Heath, 1971).] *(right)* Earth's magnetic field is much like the field that would be produced if a giant bar magnet were placed at the Earth's center and slightly inclined (11°) from the axis of rotation. Lines of magnetic force produced by such a bar magnet are shown. A compass needle points to the north magnetic pole because it orients in the direction of the local line of force.

Key Figure 2.10 Magnetic mapping can measure the rate of seafloor spreading.

An oceanographic survey over the Reykjanes Ridge, part of the Mid-Atlantic Ridge southwest of Iceland, showed an oscillating pattern of magnetic field strength. This figure illustrates how scientists worked out the explanation of this pattern.



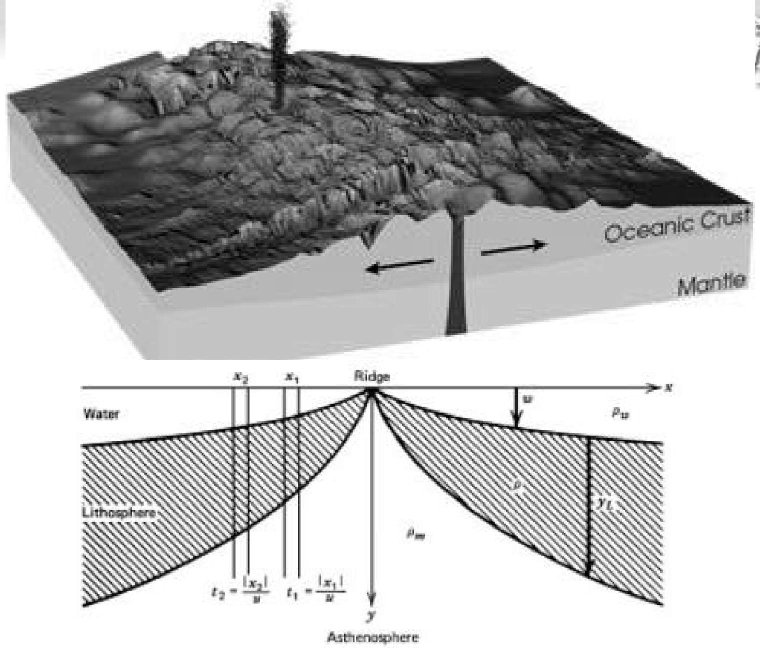
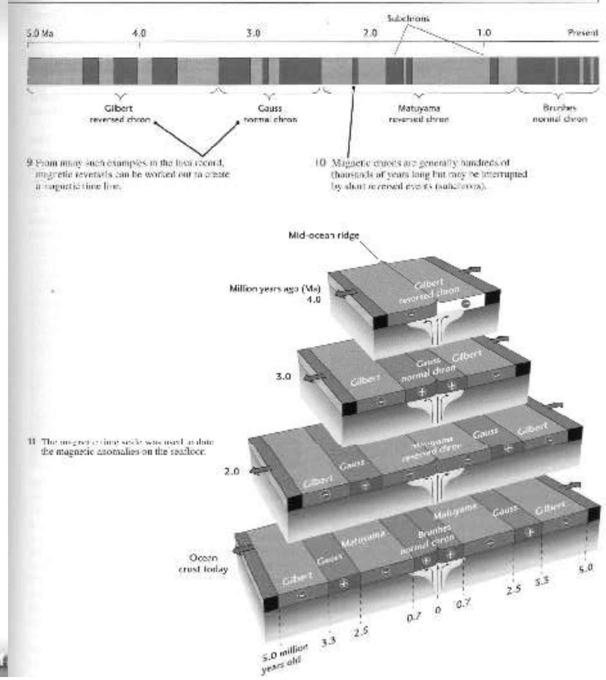


Figure 4.44 The principle of isostasy requires the ocean to deepen with age to offset the thermal contraction in the lithosphere.



36 | CHAPTER 2 Plate Tectonics: The Unifying Theory

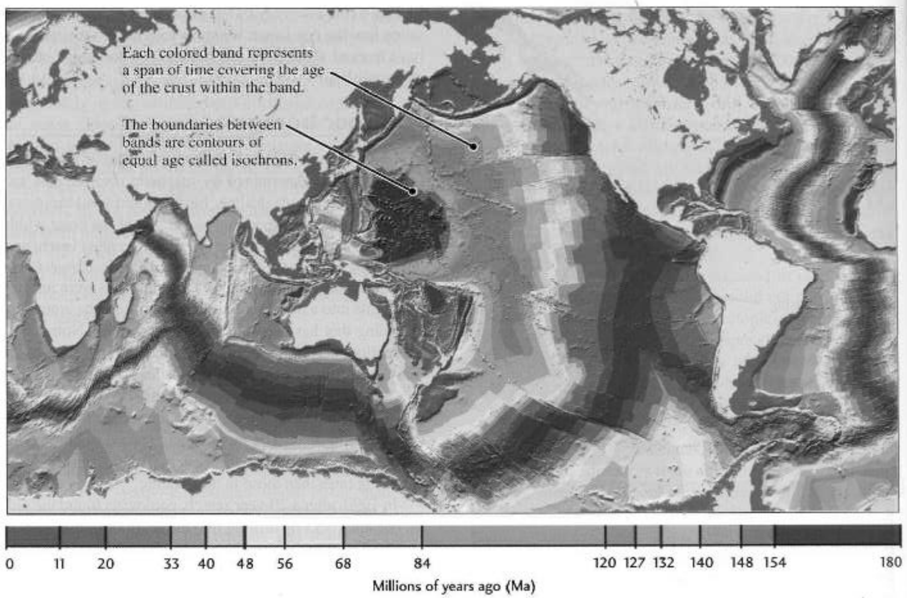


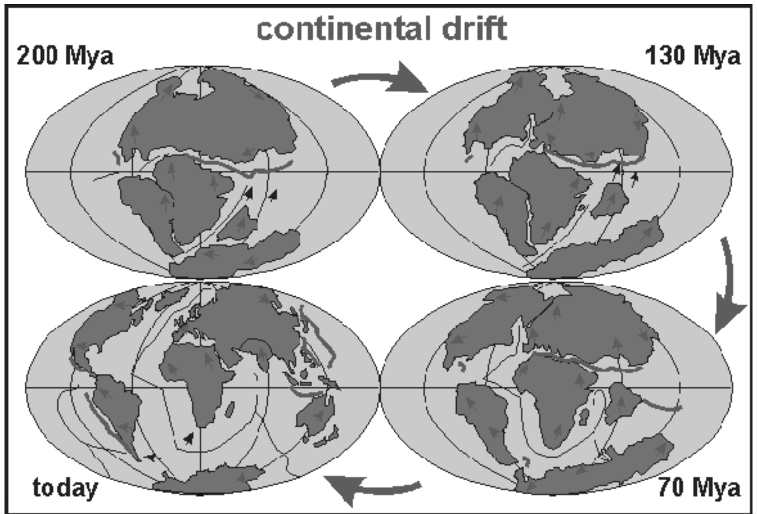
Figure 2.12 Age of seafloor crust. Each colored band represents land. Dark gray indicates shallow water over continental shelves.

Geothermics

Energy sources on Earth

- ✓ Earth's internal energy
- ✓ Radioactive element
- ✓ Solar energy

Continental drift



Energy we use

- ✓ Oil and gas
- ✓ Coal
- ✓ Hydro power
- ✓ Geothermal
- ✓ Nuclear power
- ✓ Sun light
- ✓ Wind power
- ✓ Biomass
- ✓ Wave

Heat transfer

✓ **Conduction**
the energy flow from a higher temperature to lower temperature region

✓ **Convection**
the movement of a fluid, typically in response to heat

✓ **Advection**
the movement of some material dissolved or suspended in the fluid

✓ **Radiation**
electromagnetic waves travel through a vacuum

The surface heat flow q is defined as below.

$$q = \kappa \cdot \Delta T$$

ΔT: temperature gradient (K/m)
k: Thermal conductivity (W/(m・K))

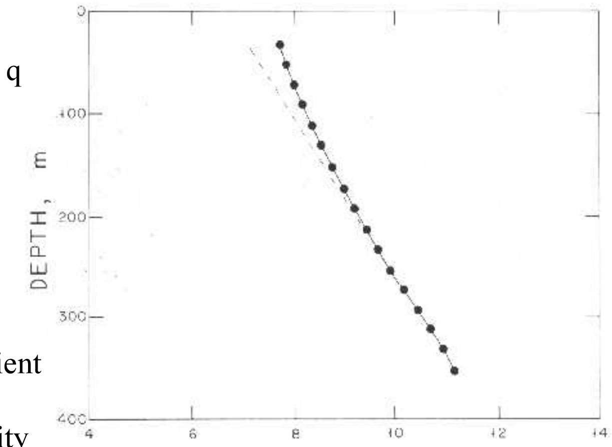
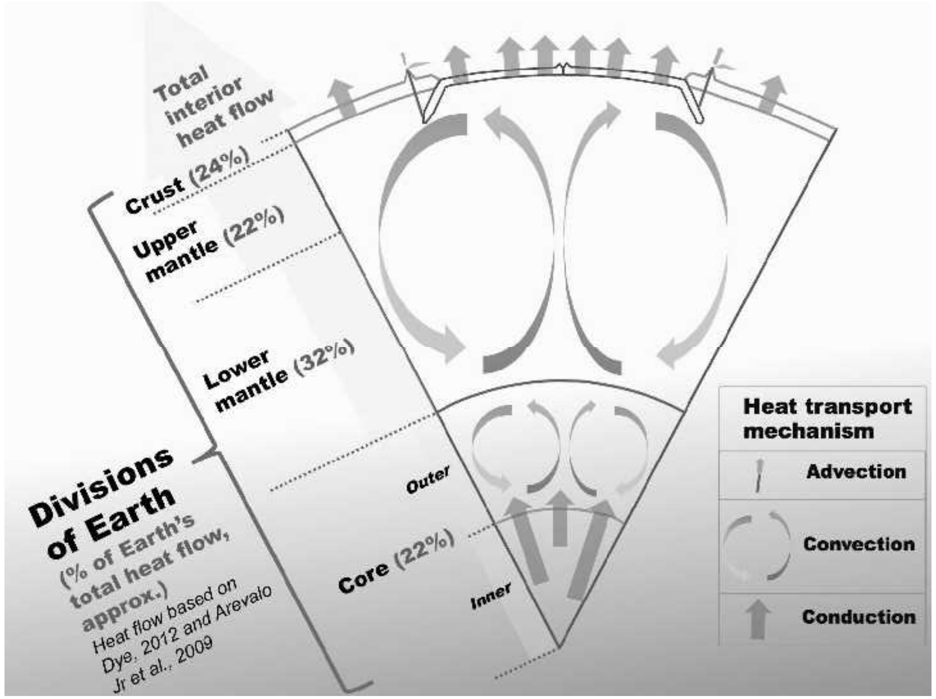
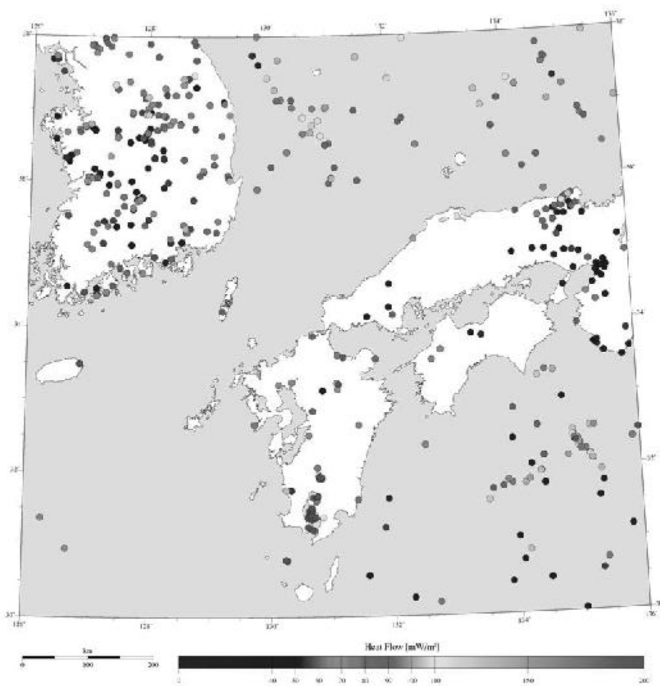
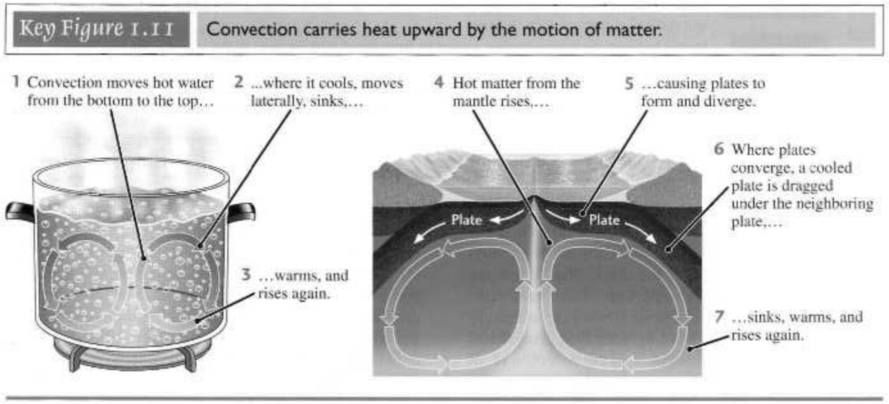


Fig. 4. Temperatures measured in the drill hole at Blodgett Forest, California. Dashed line represents temperatures corrected for a steady-state temperature anomaly of +0.5°C in the clearing.

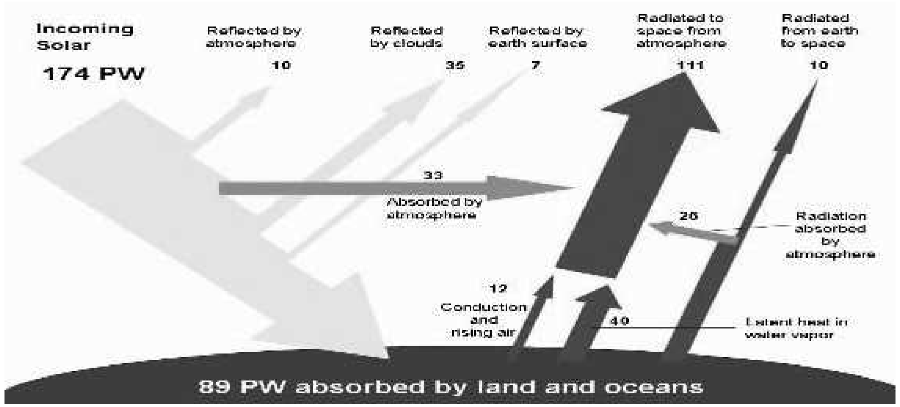




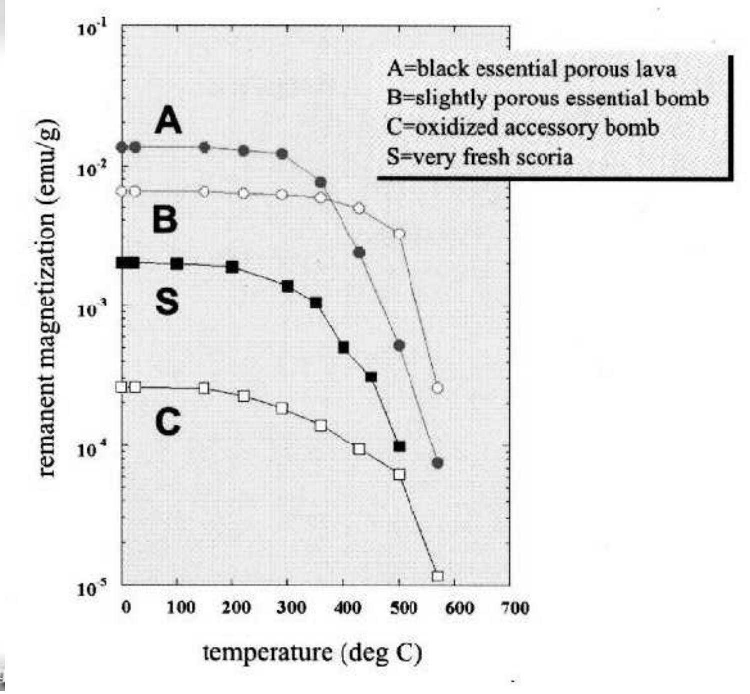


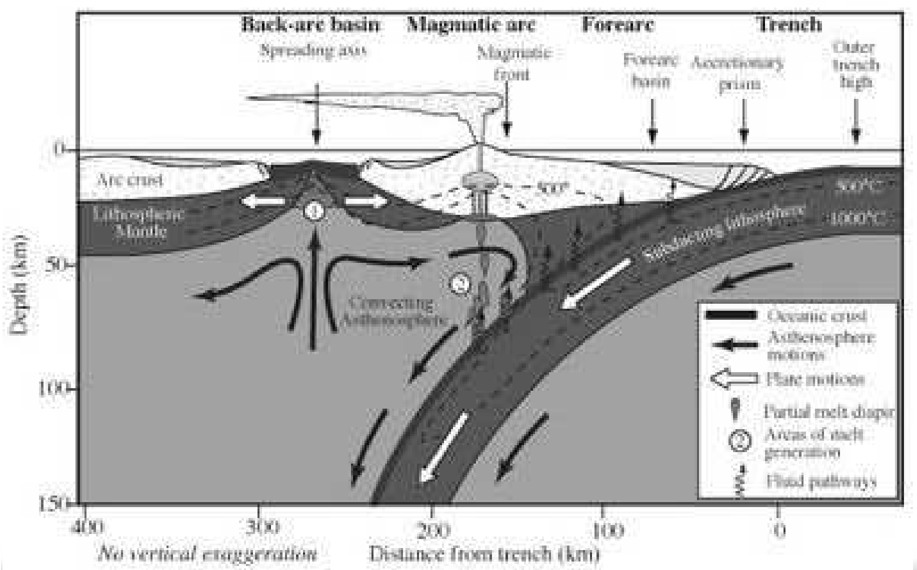
Curie depth analysis

Solar Energy Balance

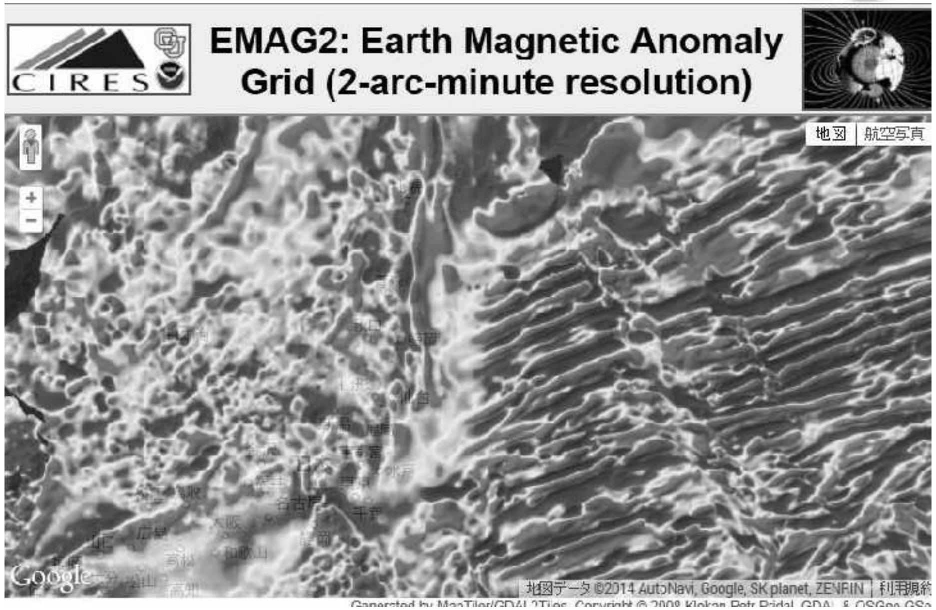


Basaltic lavas contain iron-bearing minerals such as magnetite which act like compasses. That is, as these iron-rich minerals cool below their Curie point, they become magnetized in the direction of the surrounding magnetic field. Studies of ancient magnetism (paleomagnetism) recorded in rocks of different ages provide a record of when the Earth's magnetic field reversed its polarity.

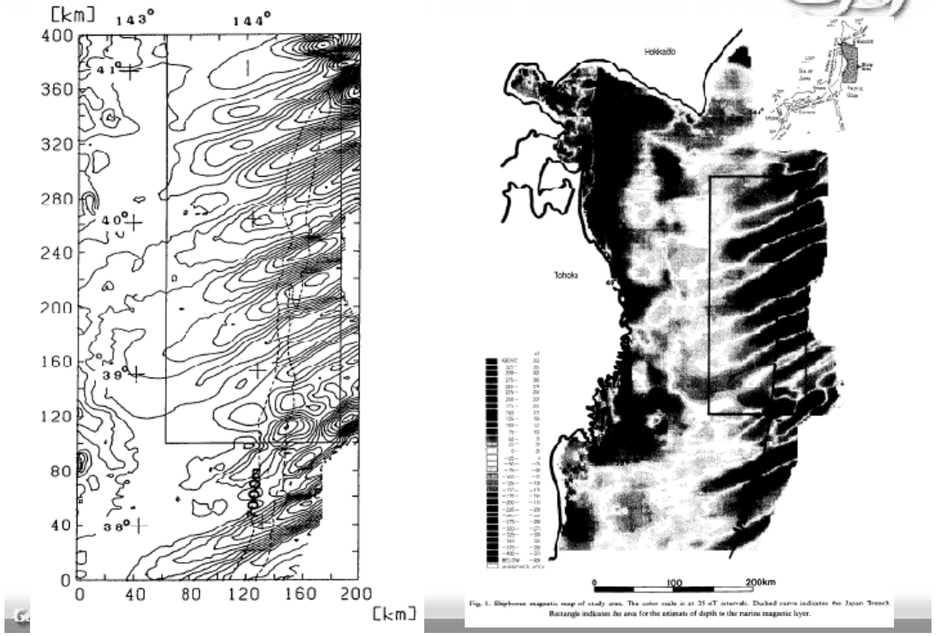




EMAG2 in Google Maps



Subduction zone



Subduction zone

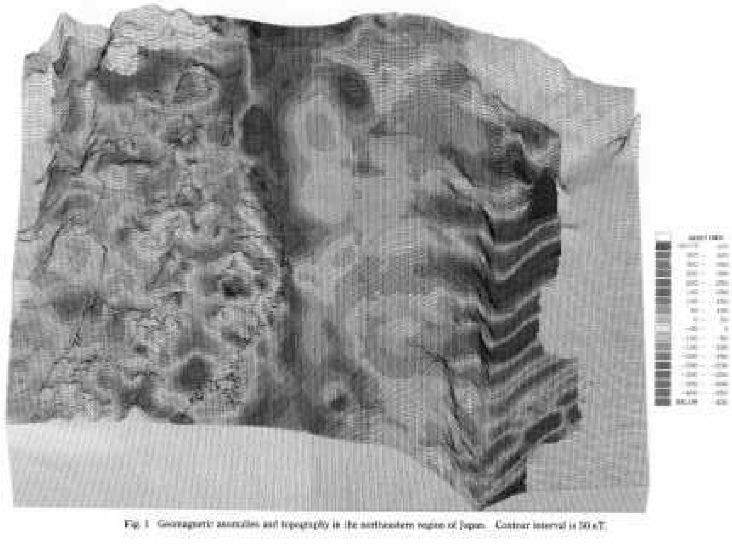
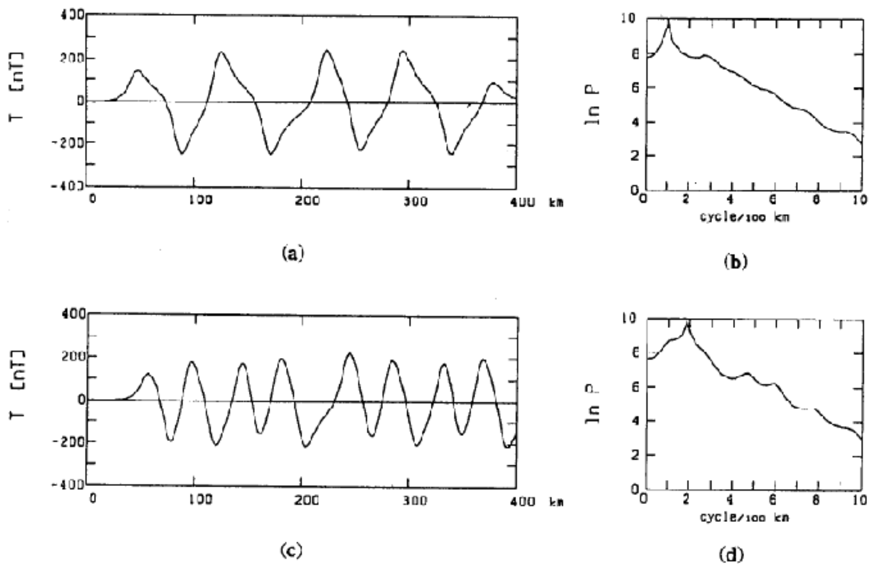
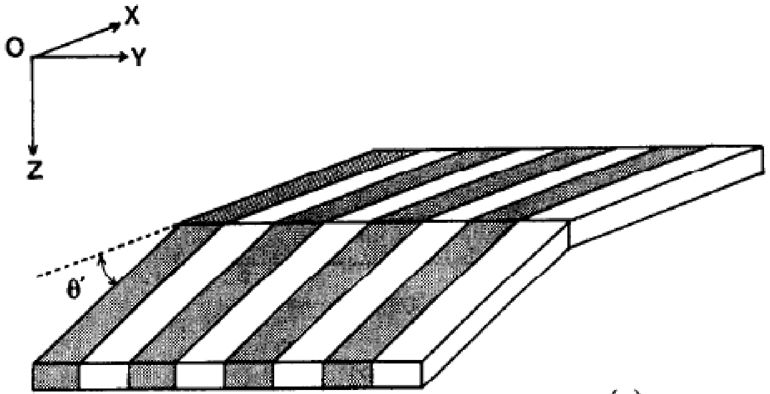


Fig. 1 Geomagnetic anomalies and topography in the northeastern region of Japan. Contour interval is 50 nT.

Magnetic anomaly across lineation



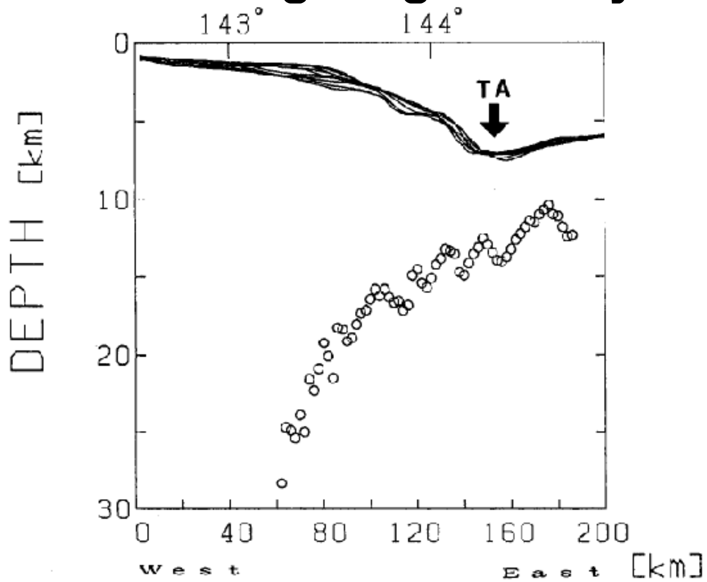
Subduction zone



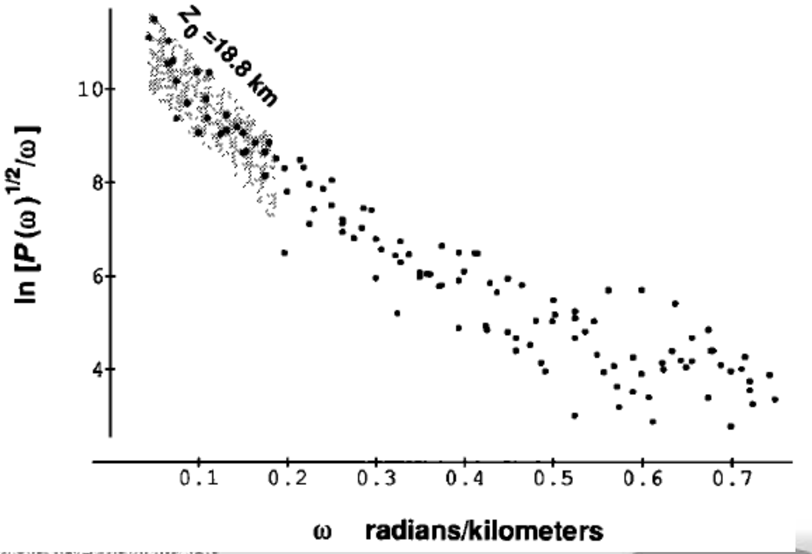
(a)

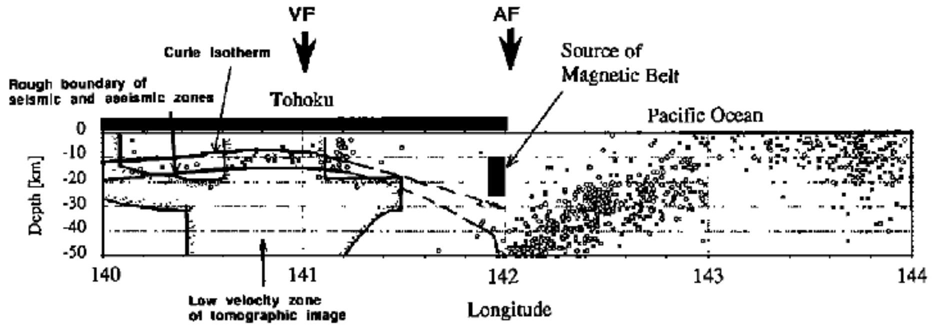
Magnetic lineation over descending plate

Descending magnetic layer

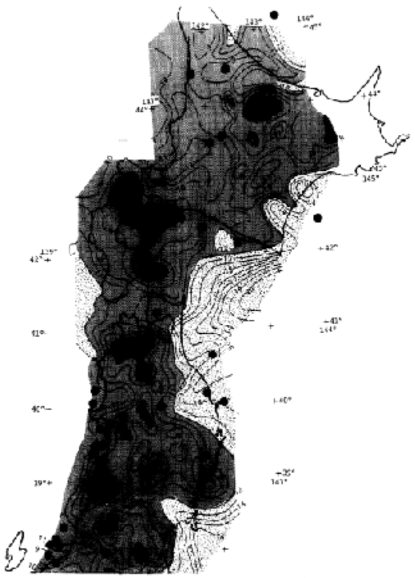


Power spectrum of 2-D magnetic data





Curie point depth



Subduction zone

OKUBO AND MATSUNAGA: CURIE POINT DEPTH IN NORTHEAST JAPAN

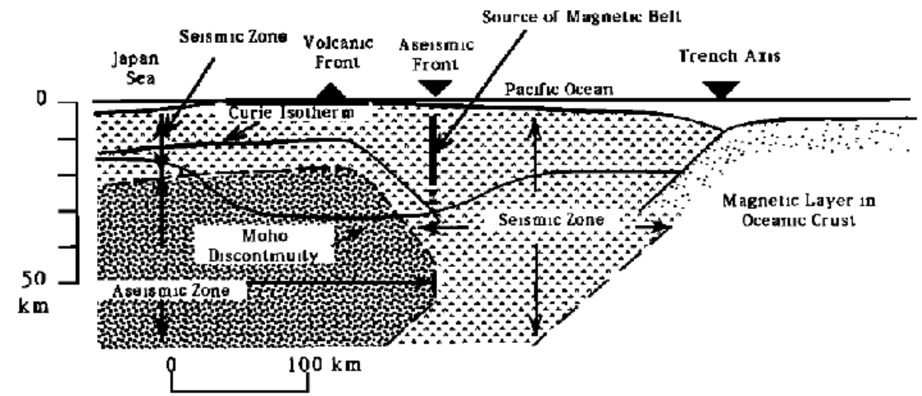


Figure 10. Summarized cross section around 41°N (B-B′ profile).