海底熱水鉱床の形成場の時空とテクトニクス

＜地質時代の海底熱水鉱床＞
分布・形成場

＜現世の海底鉱床＞
フィリピン海

東京大学大学院新領域創成科学研究科
飯笹幸吉

Pangea
http://www.divediscover.whoi.edu/tectonics/infomod.html

火山性塊状硫化物鉱床（佐藤、1983）

- 海底火山岩あるいはその近傍に存在し、層状、レンズ状の硫化物鉱石を主体とする。
- 層準規制（stratabound）、層状（stratiform）
- Volcanogenic（火山活動と成因的関係）、volcanic-associated（記載的）。
  cf:海底噴気堆積性鉱床（submarine exhalative sedimentary deposits）
- 分類：母岩、主要金属、構造場

Volcanogenic Massive Sulphide Deposits

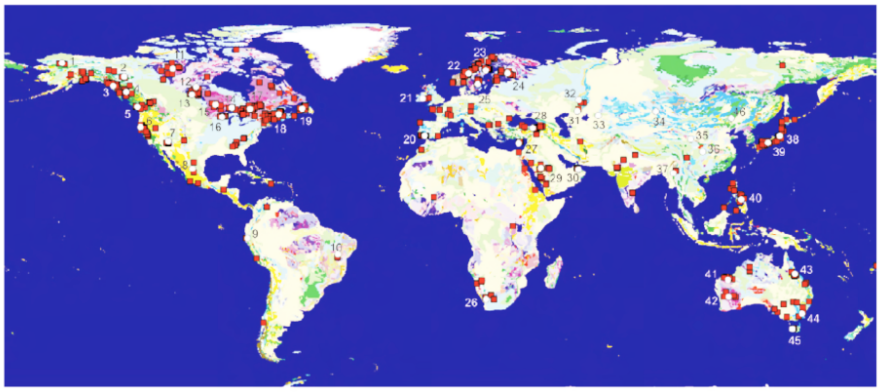


FIGURE 5. Geographical distribution of ancient VMS deposits, with major districts highlighted with respect to known aggregate geological reserves (see Table 1). Modified from Sinclair et al. (1999) and Franklin et al. (2005).

TABLE 1. Major world volcanogenic massive sulphide deposits and districts.

No.*	Deposit/District, Country	Tonnage (Mt)	No.*	Deposit/District, Country	Tonnage (Mt)
1	Brooks Range, Alaska	35	23	Skellefte, Sweden	70
2	Finlayson Lake, Yukon	20	24	Outokumpu-Pyhasalmi, Finland	90
3	Windy Craggy, BC & Green's Creek, Alaska	300	25	Bergslagen-Orsjarvi, Sweden & Finland	110
4	Northern Cordillera, British Columbia	100	26	Prenska, South Africa	45
5	Myra Falls, British Columbia	35	27	Troodos, Cyprus	35
6	Shasta, California	35	28	Black Sea, Turkey	200
7	Jerome, Arizona	40	29	Saudi Arabia	70
8	Central Mexico	120	30	Semail, Oman	30
9	Tambo-Grande, Peru	200	31	Southern Urals, Russia / Kazakhstan	400
10	Amazonian craton, Brazil	35	32	Central Urals, Russia	100
11	Slave Province, Northwest Territories, Nunavut	30	33	Rudny Altai, Kazakhstan / Russia	400
12	Ruttan, Manitoba	85	34	Altai Shan, Mongolia	40
13	Flin Flon-Snow Lake, Manitoba	150	35	North Qilian, China	100
14	Geco, Manitouwadge, Ontario	60	36	Sanjiang, China	30
15	Sturgeon Lake, Ontario	35	37	Bawdwin-Laochang, Burma /	40
16	Ladysmith-Rhinelander, Wisconsin/Michigan	80	38	Hokuroku, Japan	80
17	Abitibi, Ontario-Quebec	600	39	Besshi, Japan	230
18	Bathurst, New Brunswick	495	40	Philippines arc	65
19	Dunnage Zone, Newfoundland	75	41-42	Pilbara, Yilgarn Western Australia	75
20	Iberian Pyrite Belt, Spain & Portugal	1575	43	Central Queensland, Australia	80
21	Avoca, Ireland	37	44	Lachlan Fold Belt, Australia	100
22	Trondhjeim, Norway	100	45	Mt. Read, Tasmania	200
			46	Sino-Korean Platform	40

* numbers refer to Figure 5, tonnage is approximate

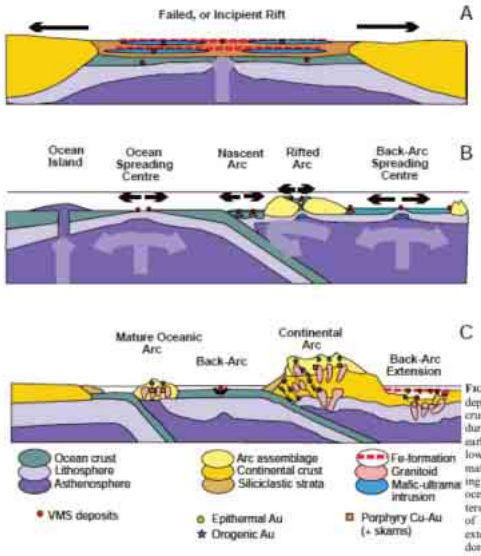


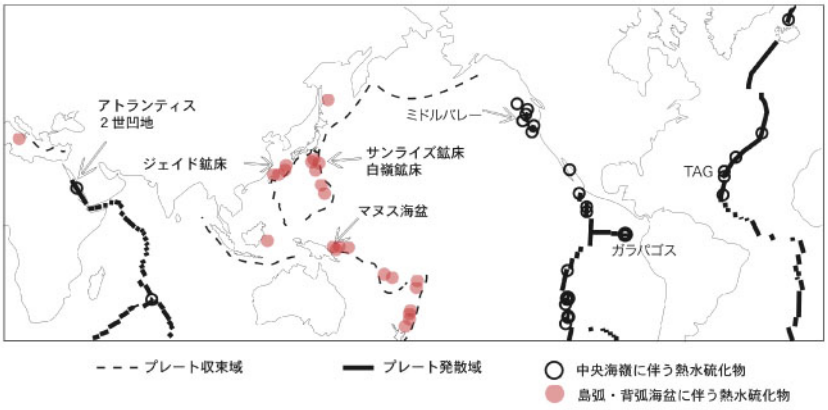
FIGURE 11. There are three principal tectonic environments in which VMS deposits form, each representing a stage in the formation of the Earth's crust. **(A)** Early Earth evolution was dominated by mantle plume activity, during which numerous incipient rift events formed basins characterized by early ocean crust in the form of primitive basalts and/or komatiites, followed by siliciclastic infill and associated Fe-formation and mafic-ultramafic sills. In the Phanerozoic, similar types of incipient rifts formed during transpressional, back-arc rifting (Windy Craggy). **(B)** The formation of ocean basins was associated with the development of ocean spreading centers along which mafic-dominated VMS deposits formed. The development of subduction zones resulted in oceanic arc formation with associated extensional domains in which bimodal mafic, bimodal felsic, and mafic-dominated VMS deposits formed. **(C)** The formation of mature arc and ocean-continent subduction fronts resulted in successor arc and continental volcanic arc assemblages that host most of the felsic-dominated and bimodal siliciclastic deposits. Thin black arrows represent direction of extension and thick, pale arrows represent mantle movement. Modified from Groves et al., 1998

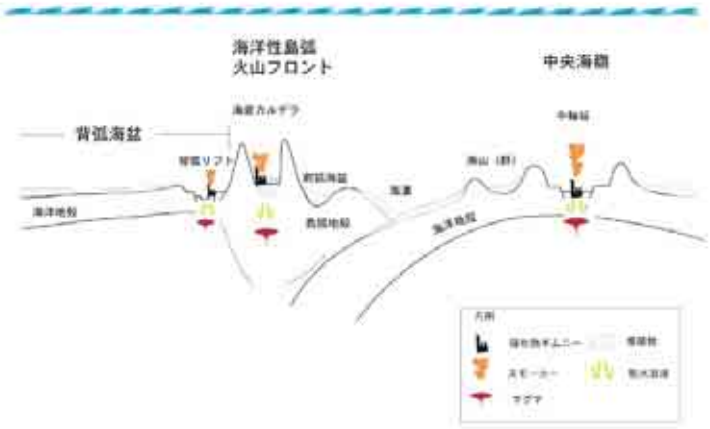
火山性塊状硫化物鉱床

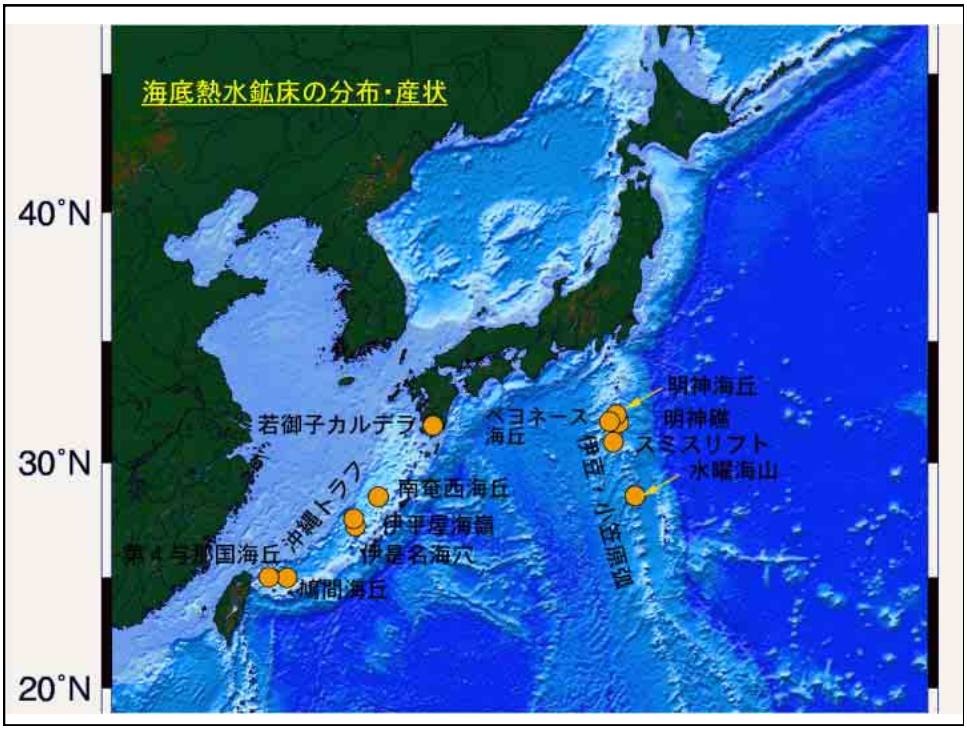
・ 島弧リフト
酸性岩→黒鉱型鉱床

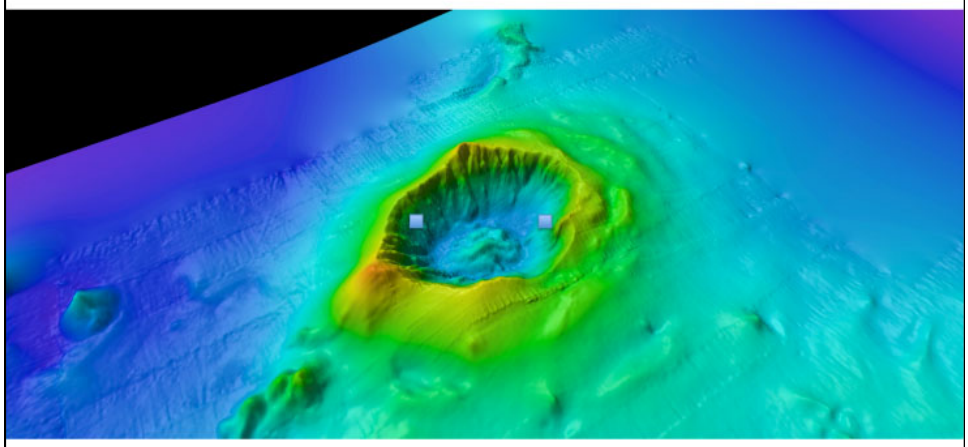
・中央海嶺、背弧海盆拡大軸
玄武岩（オフィオライト層序）→キプロス型

苦鉄質火山岩類（砂岩、泥岩、チャート、時には石灰岩などの堆積岩・化学沈殿岩）→別子型

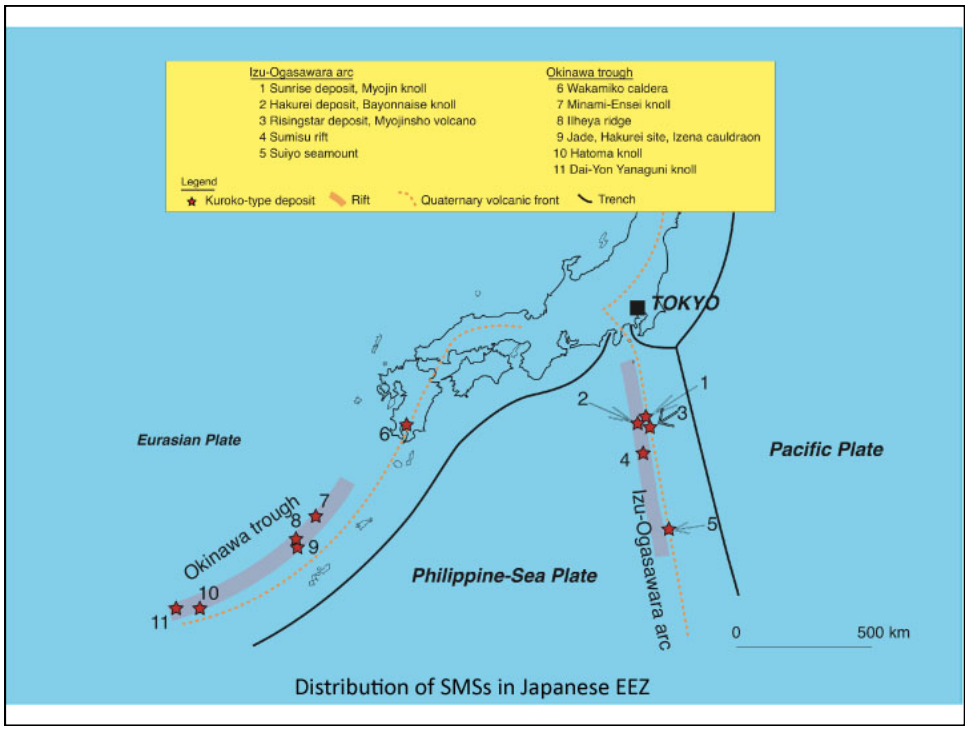



海洋性島弧
火山フロント
中央海嶺
背弧海盆

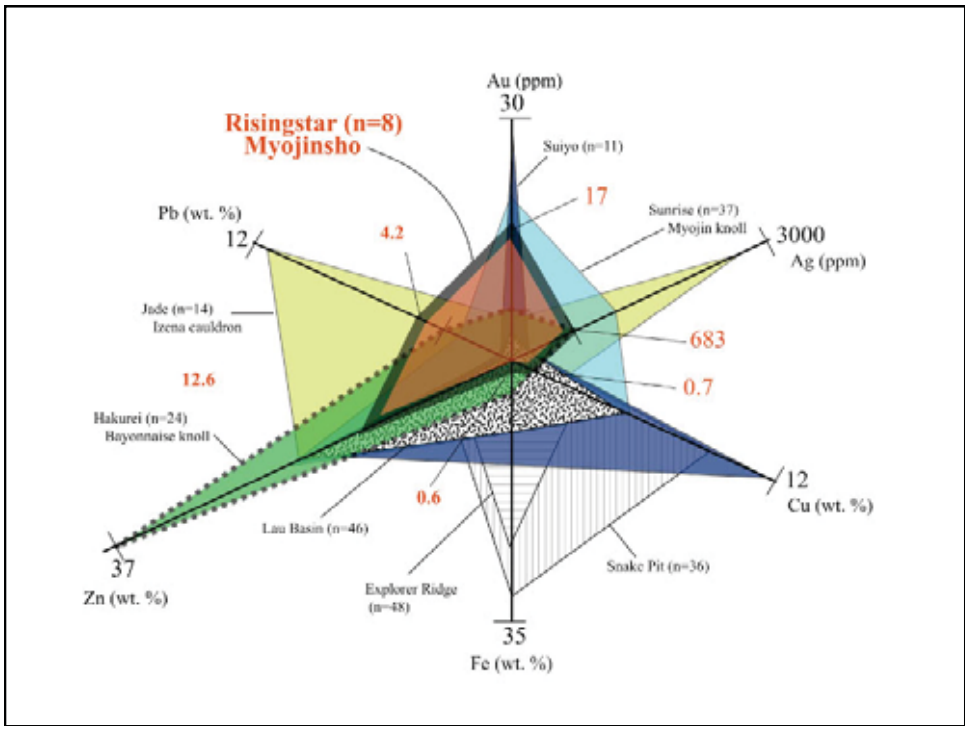

海底熱水鉱床の分布・産状
40°N
30°N
20°N
若御子カルデラ
ベヨネース
海丘
明神海丘
明神礁
スミスリフト
水曜海山
南奄西海丘
伊平屋海嶺
伊是名海穴
第４与那国海丘
鳩間海丘
沖縄トラフ
伊豆小笠原弧

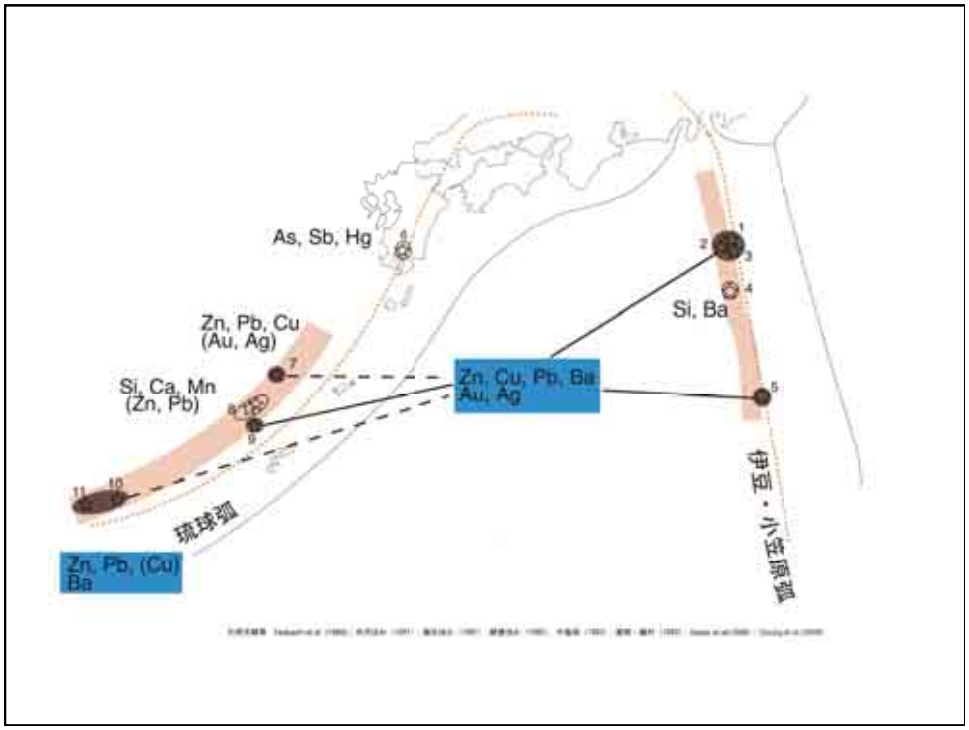


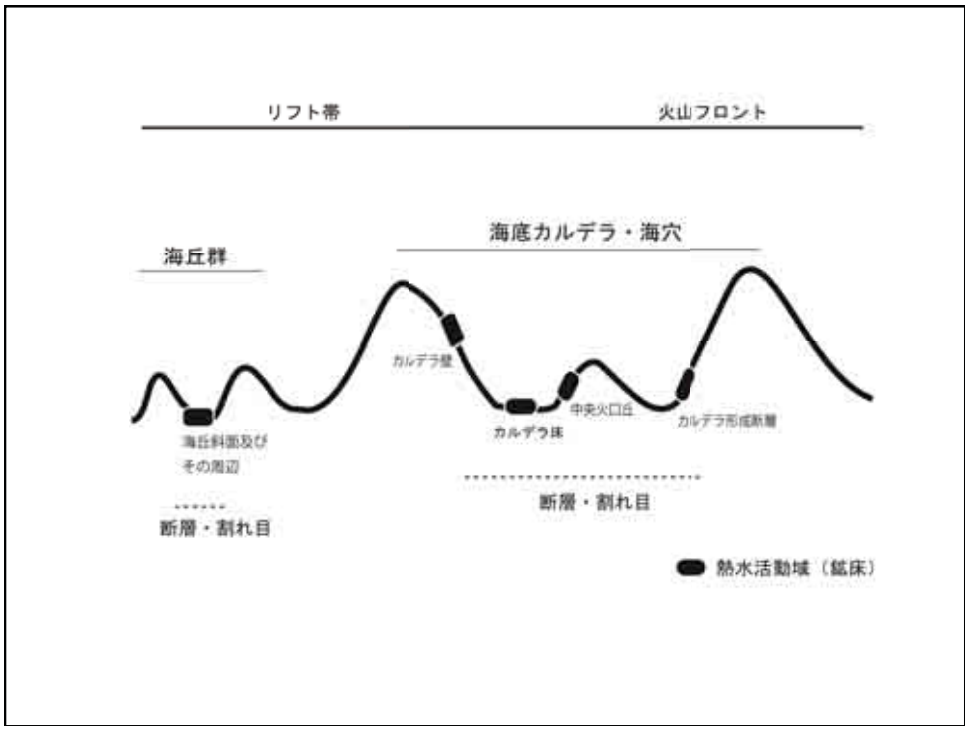
明神海丘カルデラ

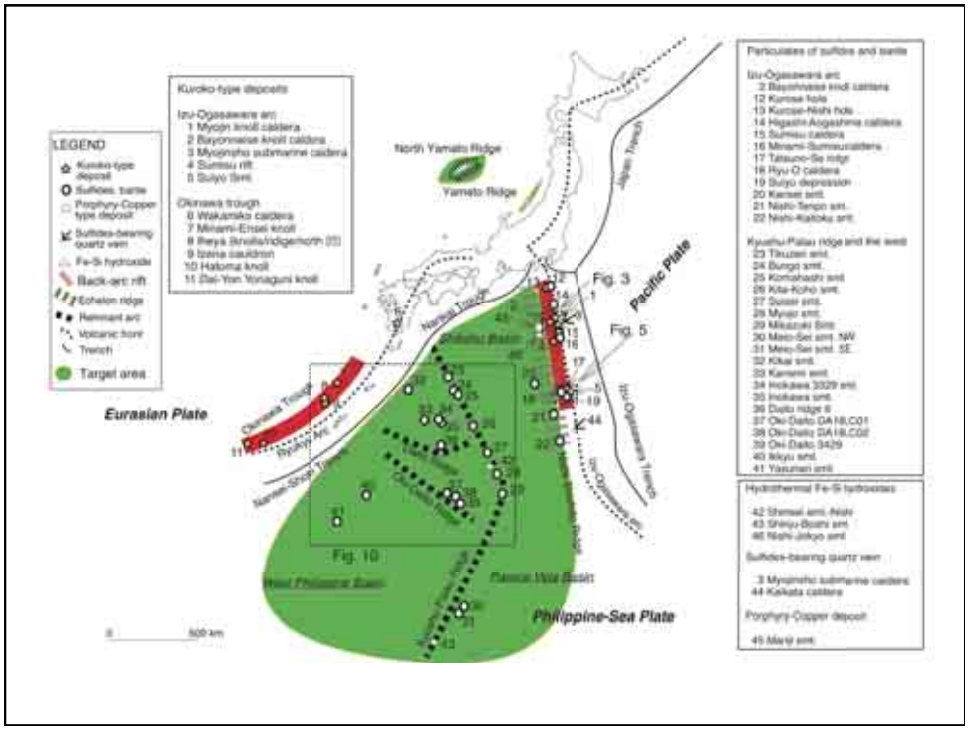


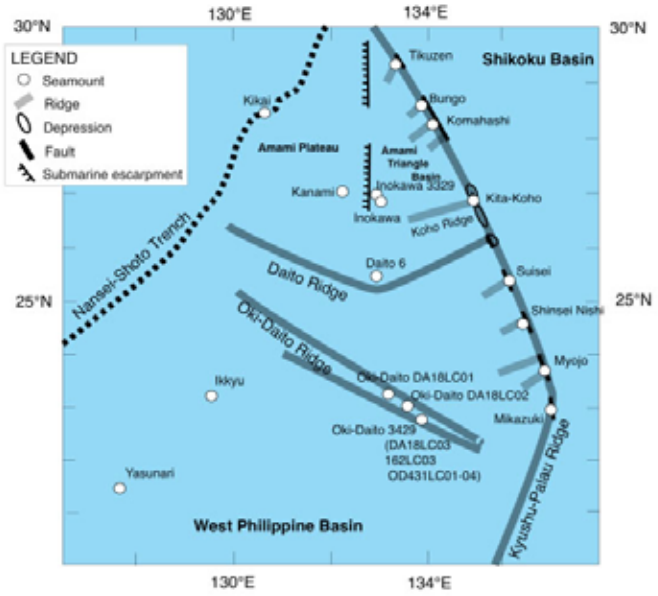
Distribution of SMSs in Japanese EEZ

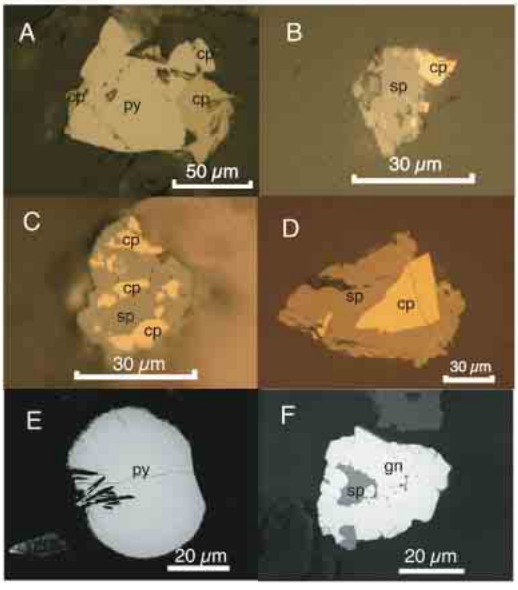

Au (ppm)
30
Risingstar (n=8)
Myojinsho
Suiyo (n=11)
17
Pb (wt. %)
12
4.2
Sunrise (n=37)
Myojin knoll
3000
Ag (ppm)
Jade (n=14)
Izena cauldron
683
12.6
0.7
Hakurei (n=24)
Bayonnaise knoll
12
Cu (wt. %)
0.6
Lau Basin (n=46)
Snake Pit (n=36)
37
Zn (wt. %)
Explorer Ridge
(n=48)
35
Fe (wt. %)


As, Sb, Hg
Zn, Pb, Cu
(Au, Ag)
Si, Ba
Si, Ca, Mn
(Zn, Pb)
Zn, Cu, Pb, Ba
Au, Ag
琉球弧
Zn, Pb, (Cu)
Ba
伊豆・小笠原弧


リフト帯
火山フロント
海丘群
海底カルデラ・海穴
カルデラ壁
中央火口丘
カルデラ床
カルデラ形成断層
海丘斜面及び
その周辺
断層・割れ目
断層・割れ目
熱水活動域（鉱床）


LEGEND
Kuroko-type deposit
Sulfides, barite
Porphyry-Copper type deposit
Sulfides-bearing quartz vein
Fe-Si hydroxide
Back-arc rift
Echelon ridge
Remnant arc
Volcanic front
Trench
Target area
Kuroko-type deposits
Izu-Ogasawara arc
1 Myojin knoll caldera
2 Bayonnaise knoll caldera
3 Myojinsho submarine caldera
4 Sumisu rift
5 Sulyo Smt.
Okinawa trough
6 Wakamiko caldera
7 Minami-Ensei knoll
8 Iheya (Irrella/Irdigemorth ??)
9 Izena cauldron
10 Hatoma knoll
11 Dai-Yon Yonaguni knoll
North Yamato Ridge
Yamato Ridge
Japan Trench
Fig. 3
Fig. 5
Pacific Plate
Eurasian Plate
Philippine-Sea Plate
Fig. 10
Particulates of sulfides and barite
Izu-Ogasawara arc
2 Bayonnaise knoll caldera
12 Komae hole
13 Komae-Nishi hole
14 Higashi-Aogashima caldera
15 Sumisu caldera
16 Minami-Sumisu caldera
17 Tatsuno-Se ridge
18 Ryu-O caldera
19 Sulyo depression
20 Kamae smt.
21 Nishi-Tenpo smt.
22 Nishi-Kaitoku smt.
Kyushu-Palau ridge and the west
23 Tikuzen smt.
24 Bungo smt.
25 Kotobashi smt
26 Kita-Koho smt.
27 Sussi smt.
28 Myojo smt.
29 Mikazuki Smt.
30 Meio-Sei smt. NW
31 Meio-Sei smt. SE
32 Kikai smt.
33 Kamemi smt.
34 Inokawa 3329 smt
35 Inokawa smt.
36 Daito ridge E
37 Oki-Daito DA HLC01
38 Oki-Daito DA HLC02
39 Oki-Daito 3429
40 Ikkyu smt.
41 Yasunari smt
Hydrothermal Fe-Si hydroxides
42 Shinsei smt.-Nishi
43 Shinyu-Bostni smt
46 Nishi-Jokyo smt
Sulfides-bearing quartz vein
3 Myojinsho submarine caldera
44 Kaikata caldera
Porphyry-Copper deposit
45 Manji smt.





Representative photomicrographs (A to D) in reflected light and back-scattered images (E and F) of scanning electron microscope (SEM) showing composite particulates from LC sediments from seamounts in the Kyushu-Palau ridge, Amami plateau, and Amami triangle basin. Photos A and B show a py-cp and an sp-cp particulate, respectively, from pelagic clay with foraminifera about 270 cm deep below seafloor in the Tikuzen seamount (DA04LC01-71) at water depth of 2196 m. Photo C is a cp-sp particulate from pelagic clay with foraminifera about 50 cm below seafloor at the Kita-Koho seamount at water depth of 2763 m. Photo D indicates a cp-sp particulate from pelagic clay about 50 cm below seafloor at the Inokawa seamount at water depth of 4797 m. Back-scattered images of SEM, photos E and F, show a pelletal pyrite from foraminifera ooze with pelagic clay (Kanami seamount, AM396LC01-35), and an sp-gn particulate from ash layer (Kikai seamount, AM390LC01-50), respectively.