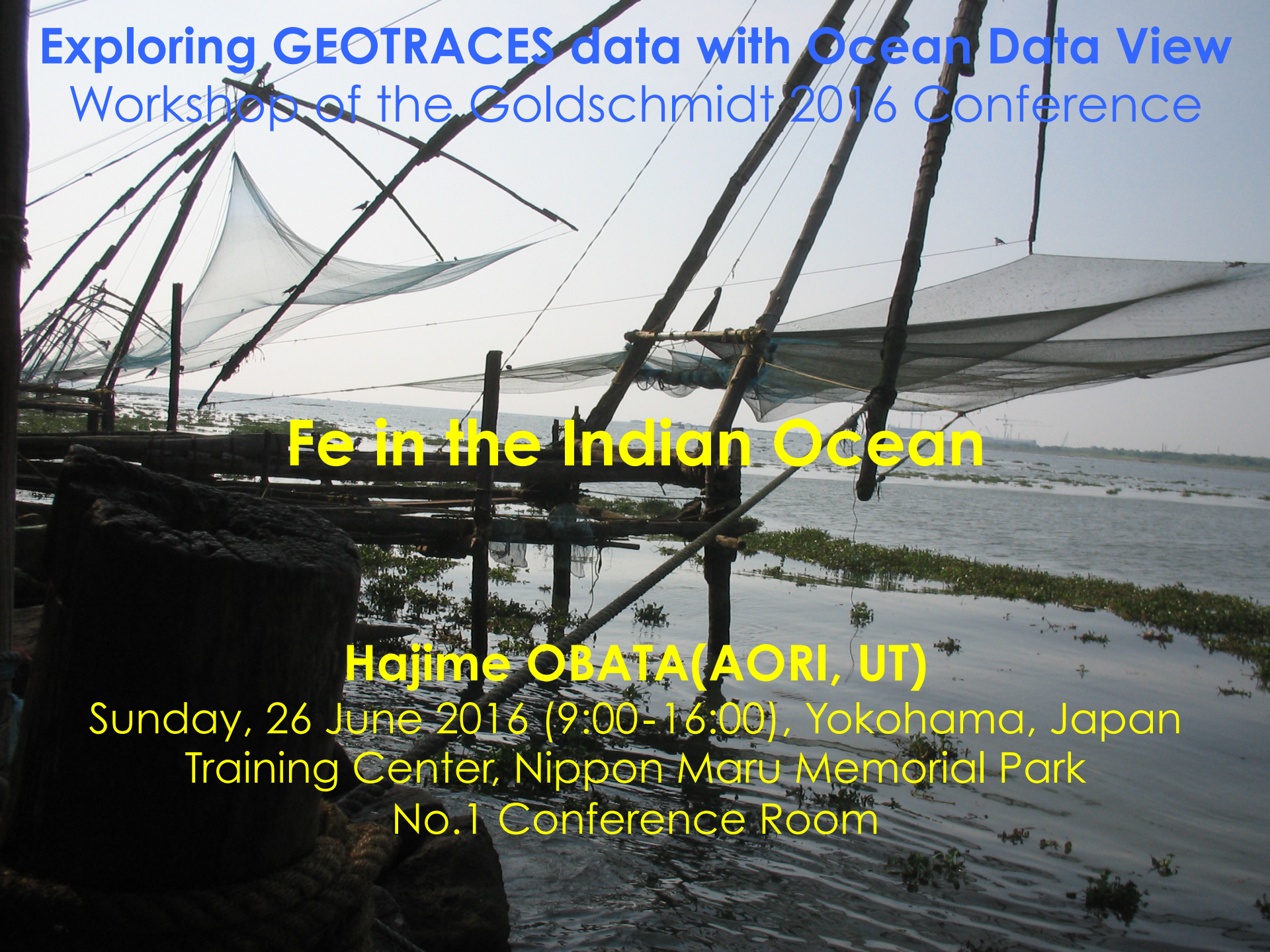
# Exploring GEOTRACES data with Ocean Data View

Workshop of the Goldschmidt 2016 Conference



## Fe in the Indian Ocean

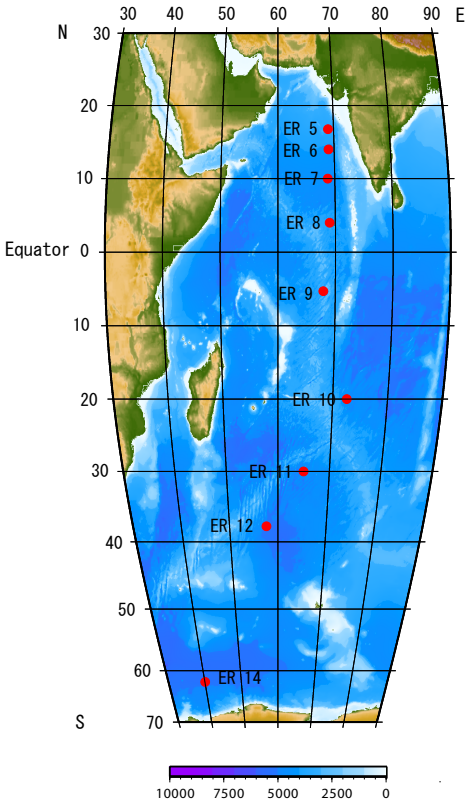
**Hajime OBATA(AORI, UT)**

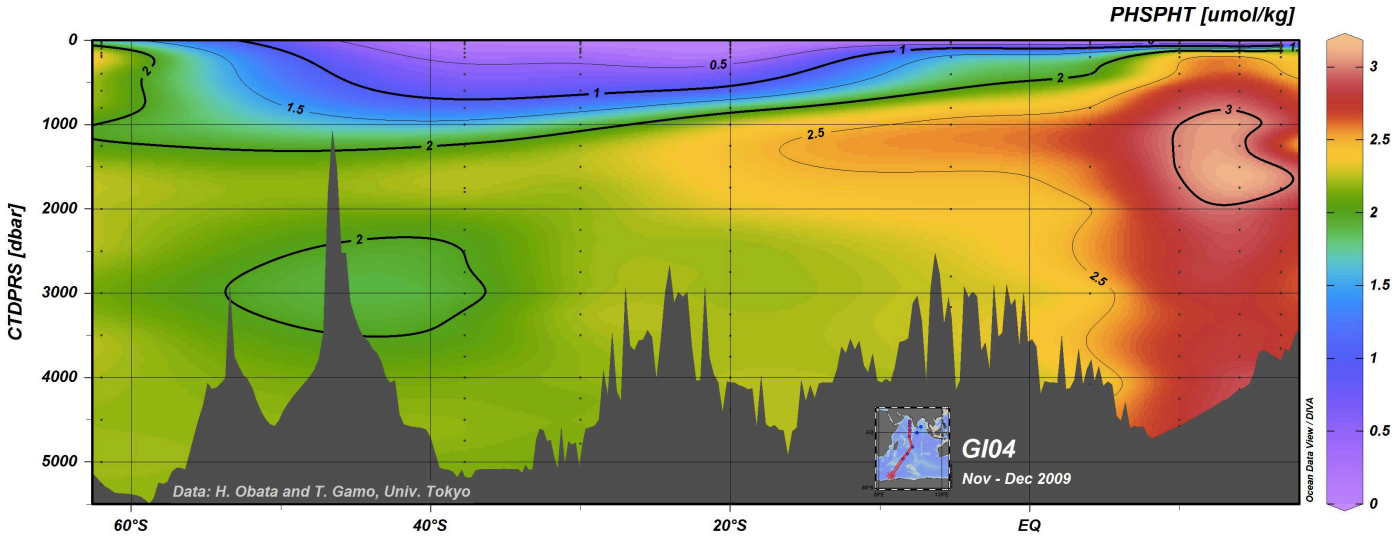
Sunday, 26 June 2016 (9:00-16:00), Yokohama, Japan

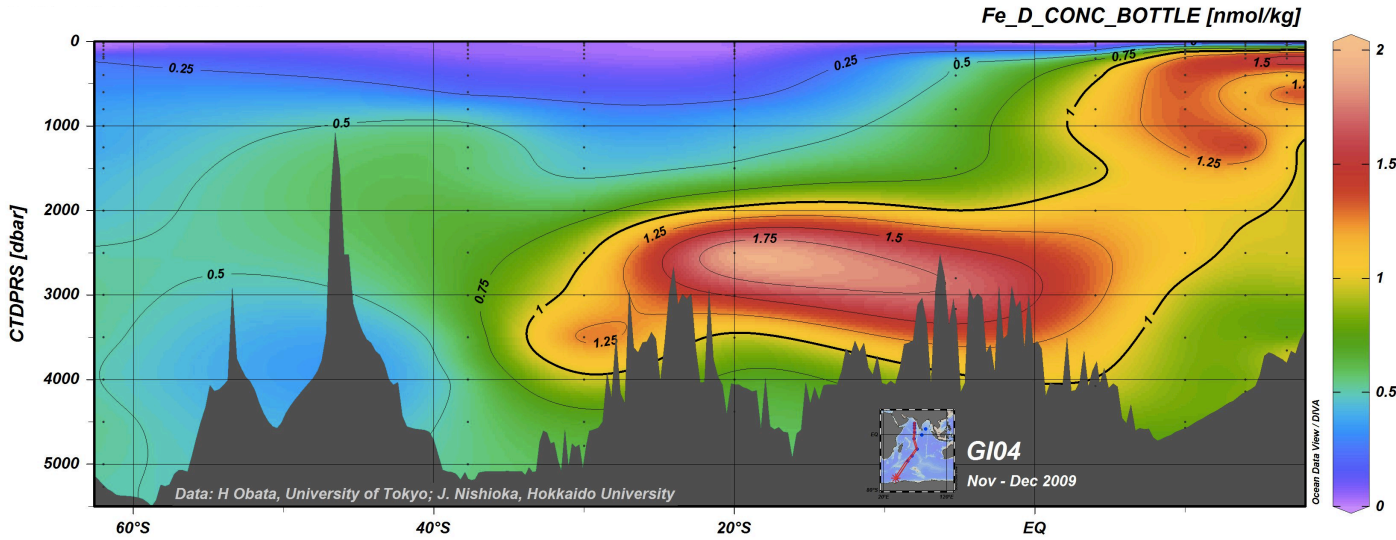
Training Center, Nippon Maru Memorial Park

No.1 Conference Room

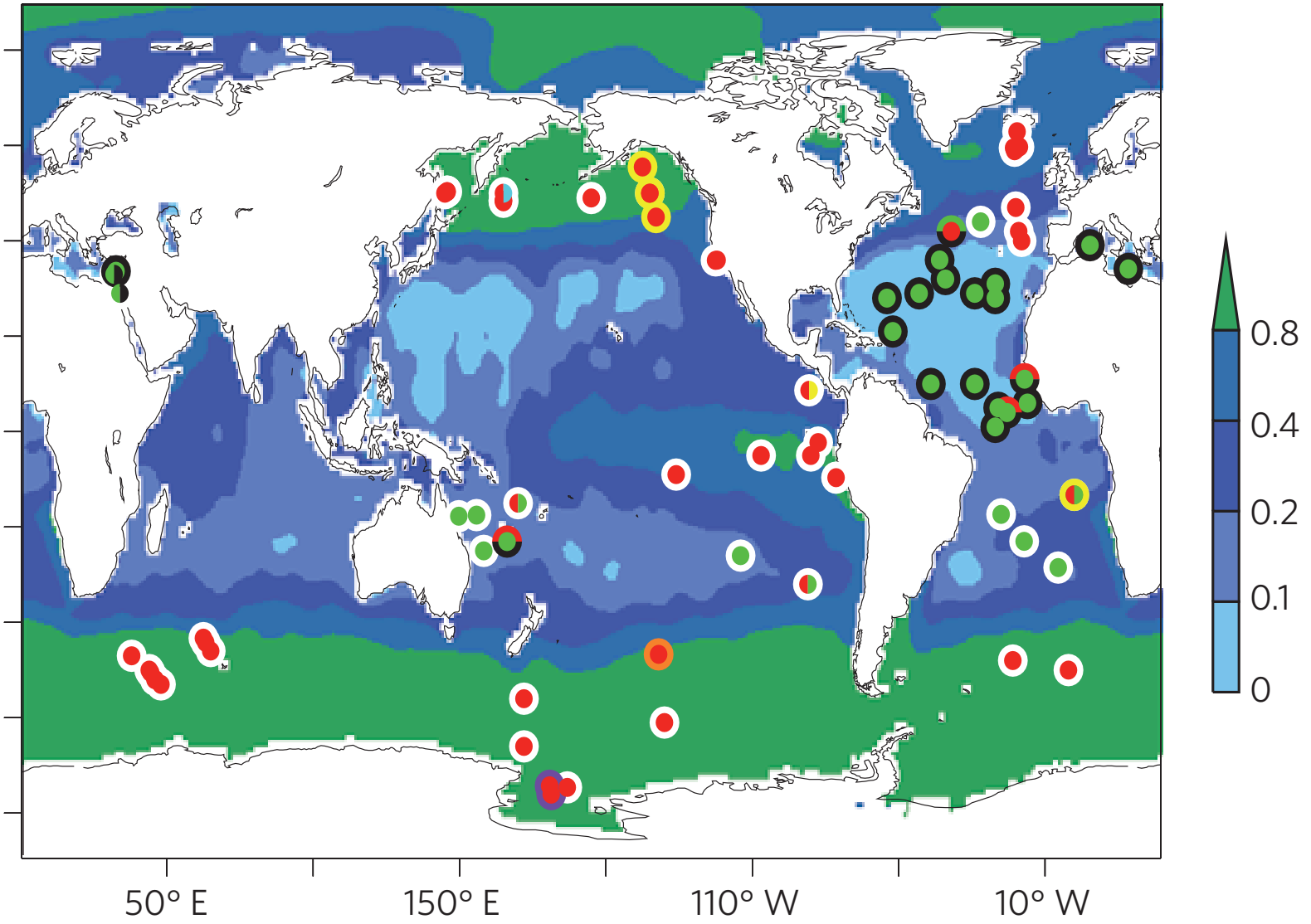
# Phosphate and Fe during GI04



# Patterns of nutrient limitation for primary production.




Backgrounds indicate annual average surface concentrations of phosphate in µmol $kg^{-1}$.
Symbols indicate the primary (central circles) and secondary (outer circles) limiting nutrients: N (green), P (black), Fe (red), Si (orange), Co (yellow), Zn (cyan) and vitamin B12 (purple).

(Moore et al., 2013)

# Global Fe flux to ocean

**Table 1.** Global iron fluxes to the ocean (in Tg of Fe year$^{-1}$). From Poulton and Raiswell (*4*), with modified atmospheric inputs from Fig. 2. "Authigenic fluxes" refer to releases from deep-sea sediments during diagenesis. We distinguish only separately dissolved and particulate for fluvial inputs, because it is clear that fluvial particulate iron, along with iron from coastal erosion and glacial sediment sources, does not reach the oceans, whereas authigenic, atmospheric, and hydrothermal iron all reach the oceans regardless of their phase.

| Source | Flux |
|---|---|
| Fluvial particulate total iron | 625 to 962 |
| Fluvial dissolved iron | 1.5 |
| Glacial sediments | 34 to 211 |
| Atmospheric | 16 |
| Coastal erosion | 8 |
| Hydrothermal | 14 |
| Authigenic | 5 |

(Jickells et al., 2005)

# Geochemical cycles at hydrothermal vents

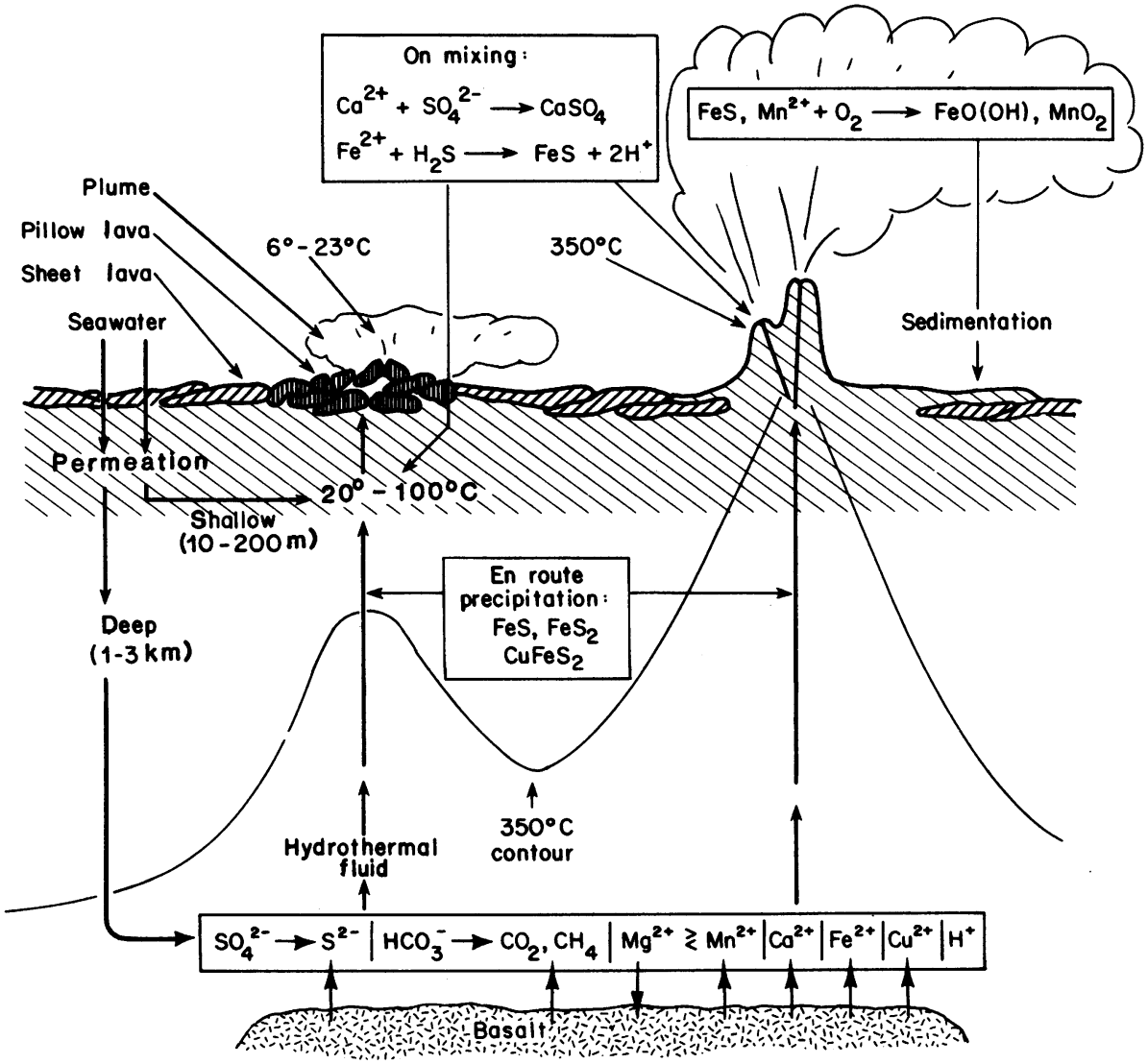
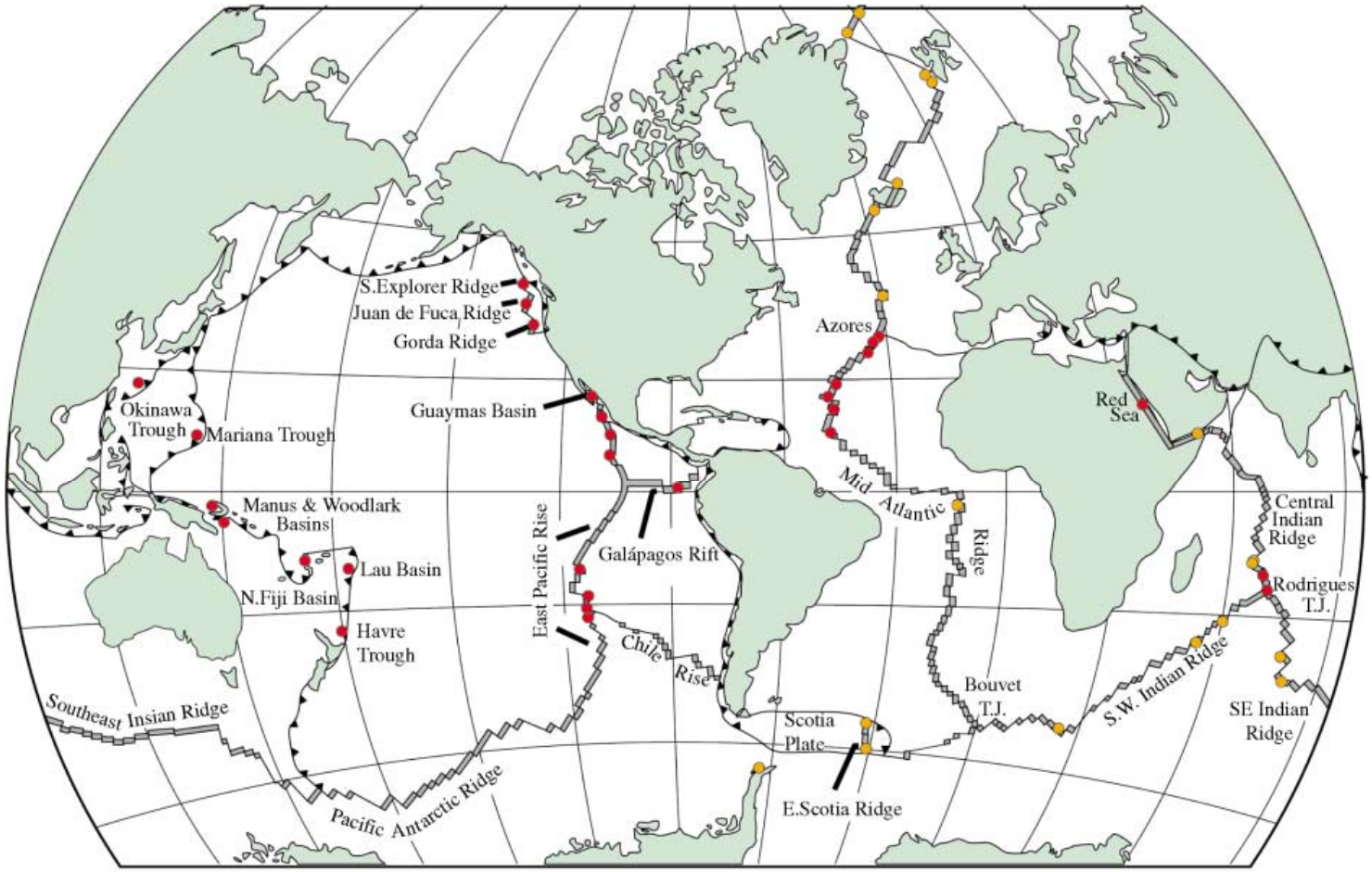



Fig. 1. Schematic diagram showing inorganic chemical processes occurring at warm- and hot-water vent sites. Deeply circulating seawater is heated to 350° to 400°C and reacts with crustal basalts, leaching various species into solution. The hot water rises, reaching the sea floor directly in some places and mixing first with cold, downwelling seawater in others. On mixing, iron-copper-zinc sulfide minerals and anhydrite precipitate. Modified from Jannasch and Taylor (*54*).

(Jannasch & Mottl, 1985)

# Hydrothermally active sites



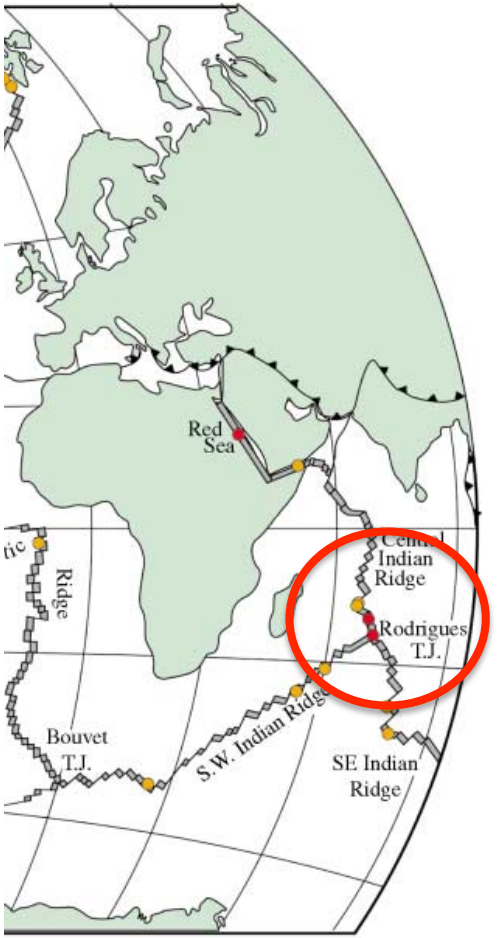

Locations of known hydrothermal activity along the global mid-ocean ridge system

● = known active sites ● = active sites indicated by midwater chemical anomalies

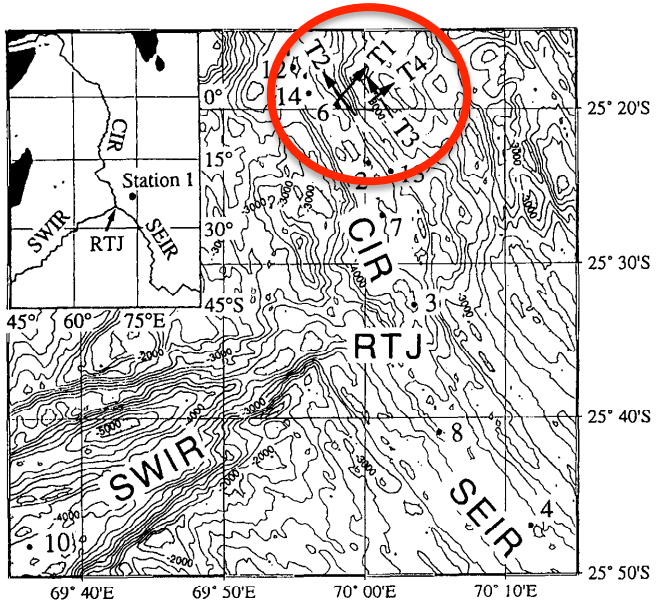
(German and Von Damm, 2003)

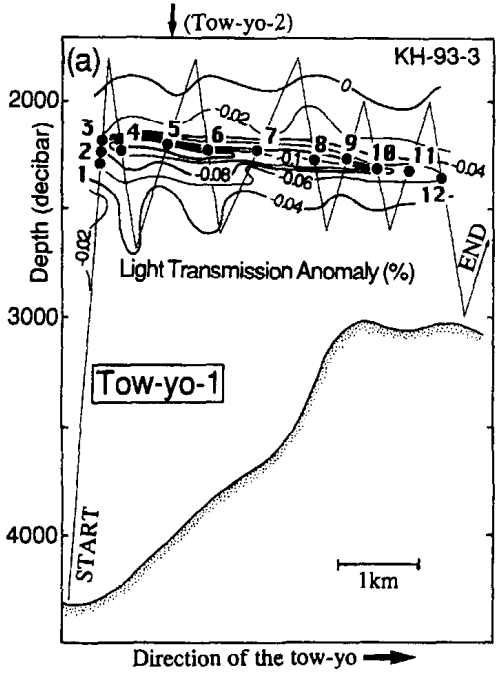
# R.V. Hakuho-maru KH-93-3 cruise

Investigation of hydrothermal activity at the Rodriguez Triple Junction
(June 8 – Sep 17, 1993)
Chemistry group: Prof. Toshi Gamo

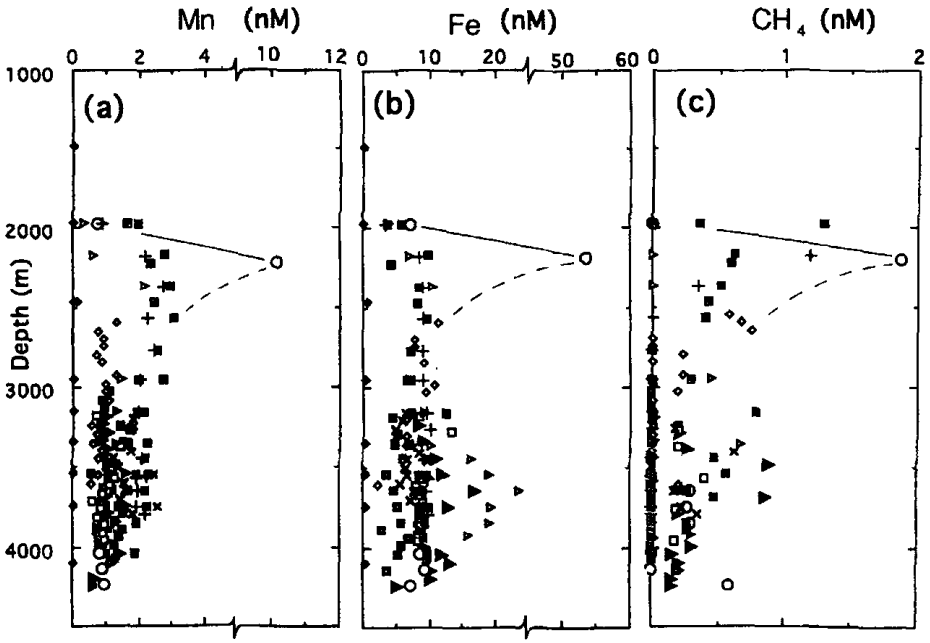


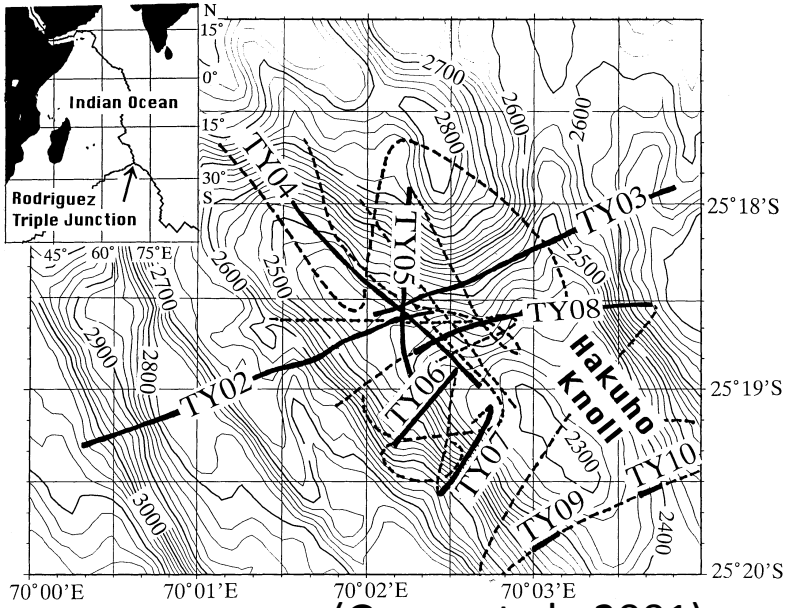
# Hydrothermal activity at the Rodriguez Triple Junction



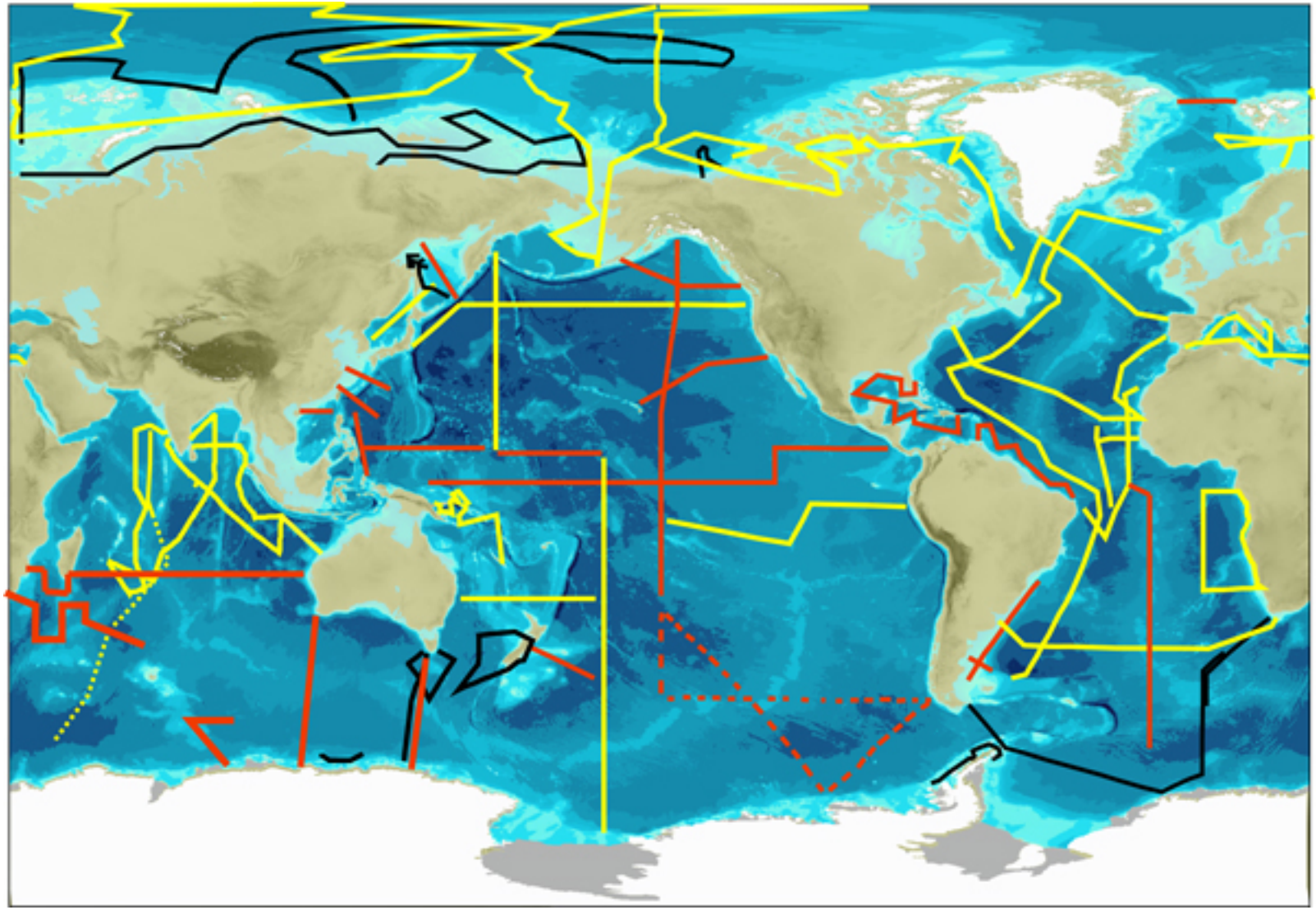

(Gamo et al., 1996)



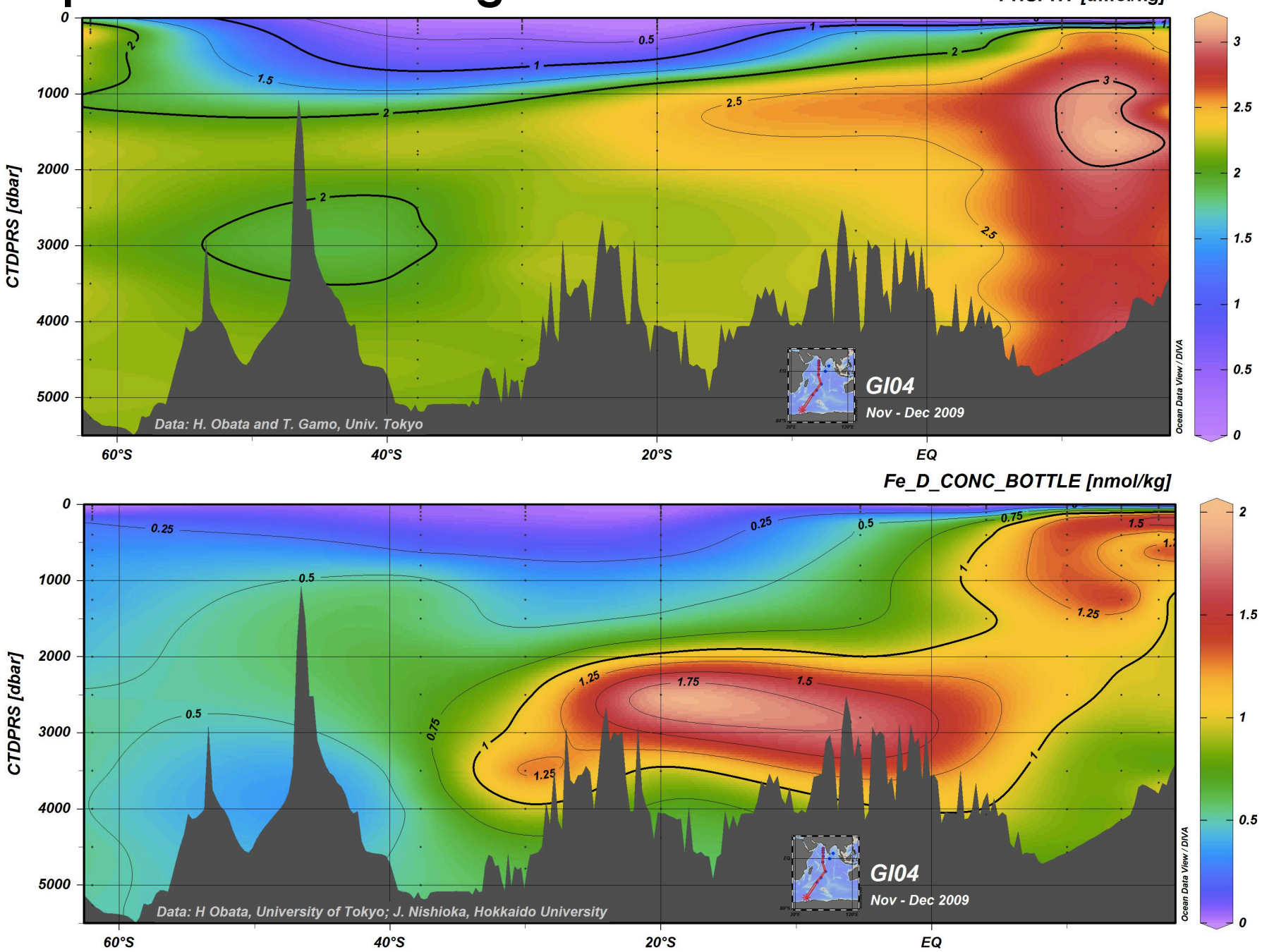




(Gamo et al., 2001)

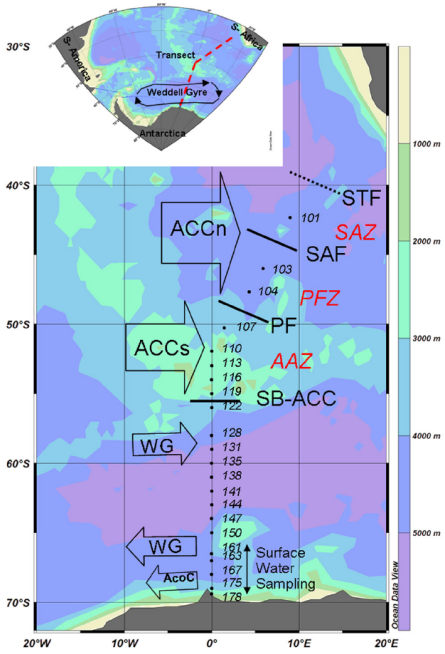
# GEOTRACES section cruises

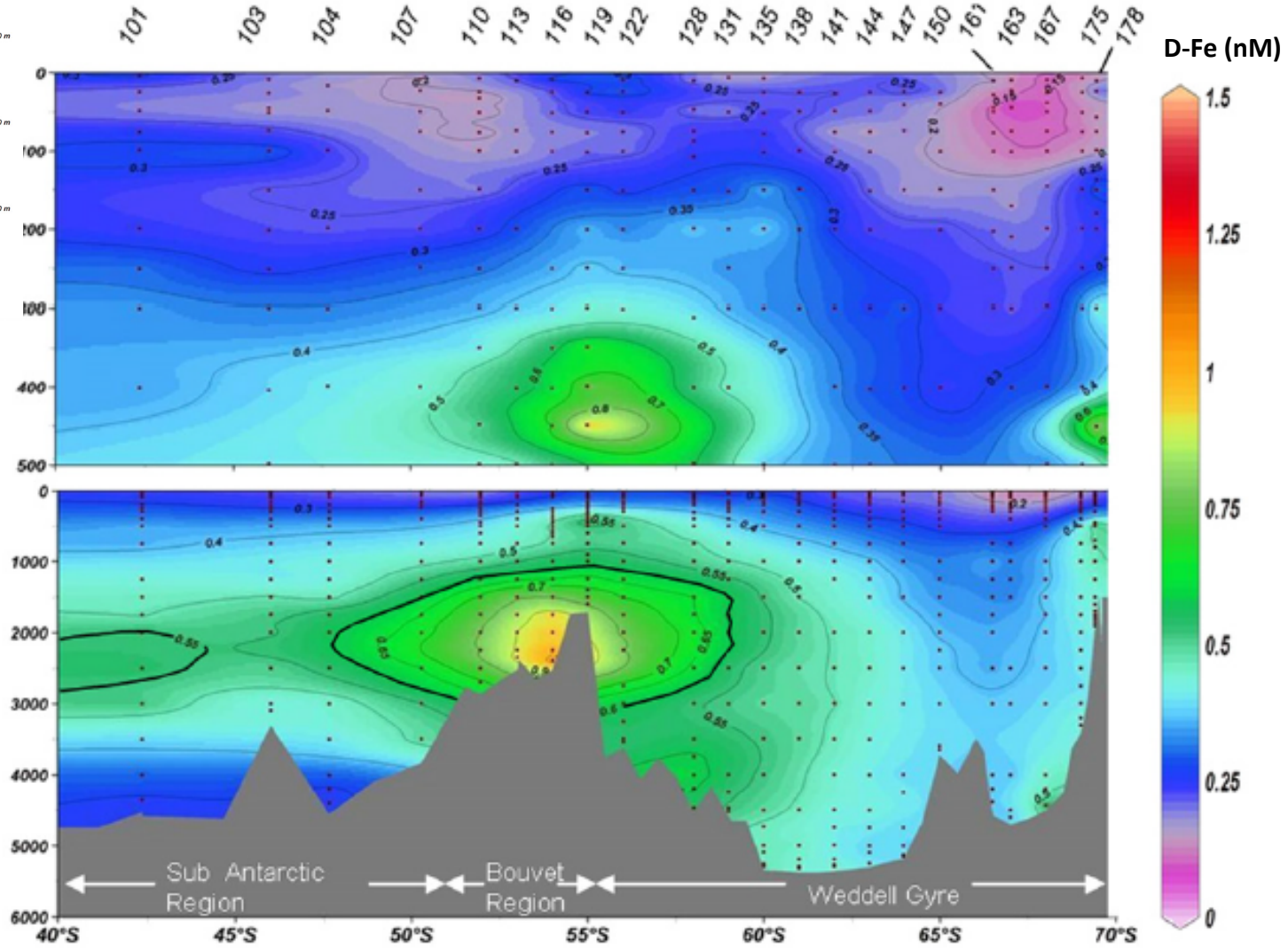


# Phosphate and Fe during GI04

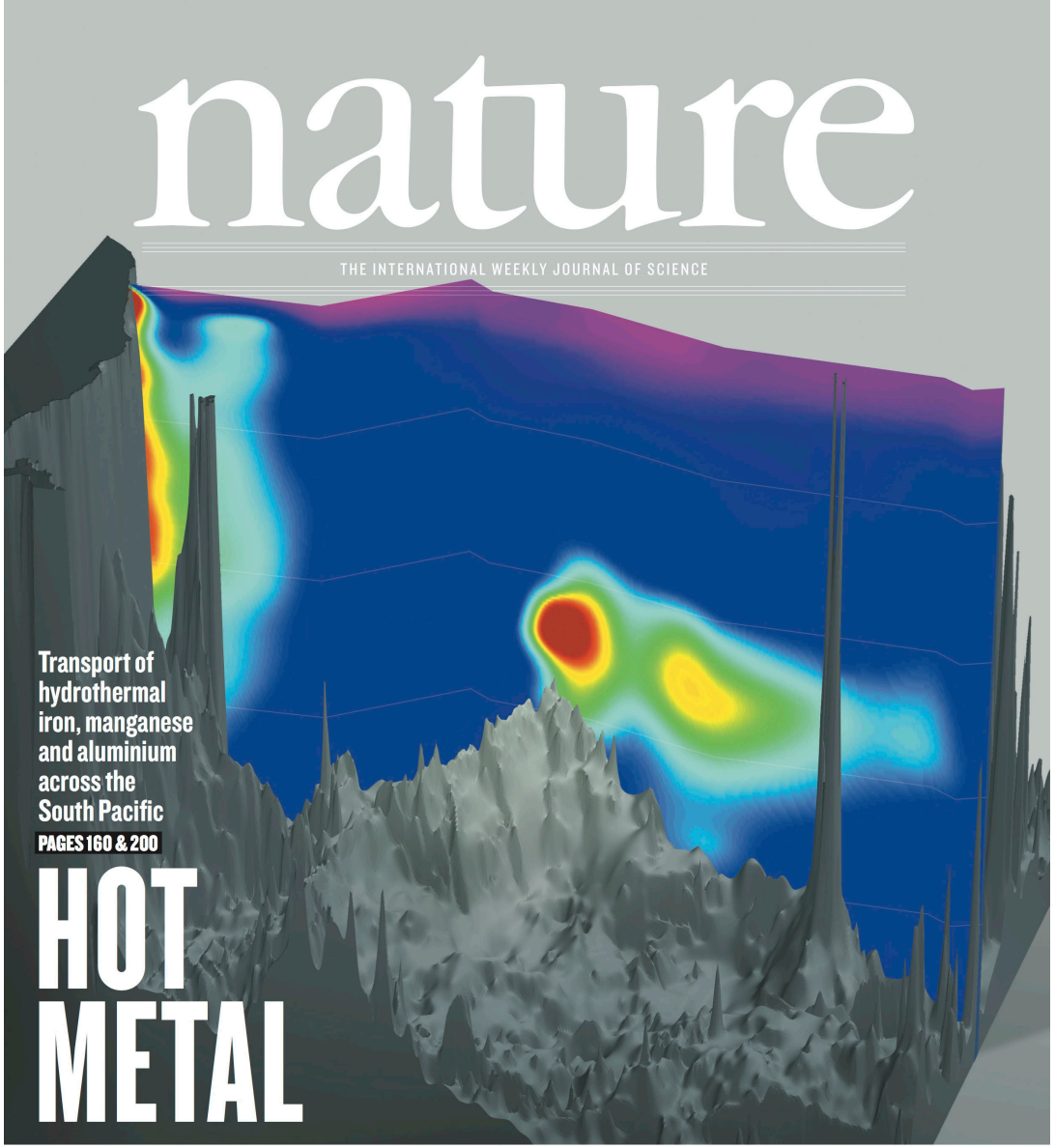


# Bouvet Region Southern Ocean




(Klunder et al., 2011)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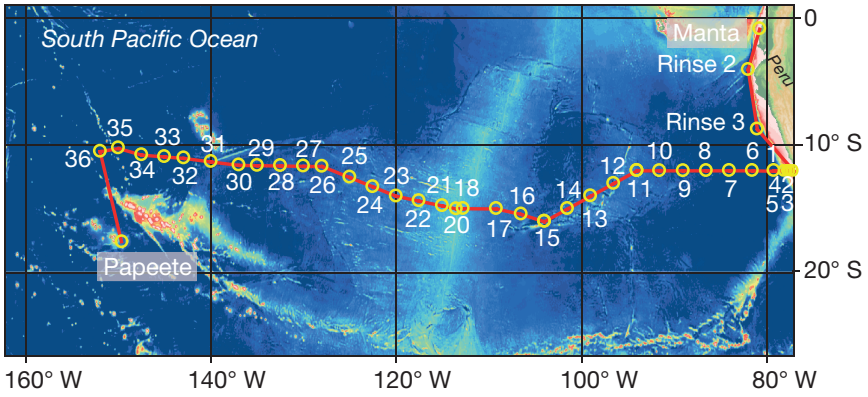
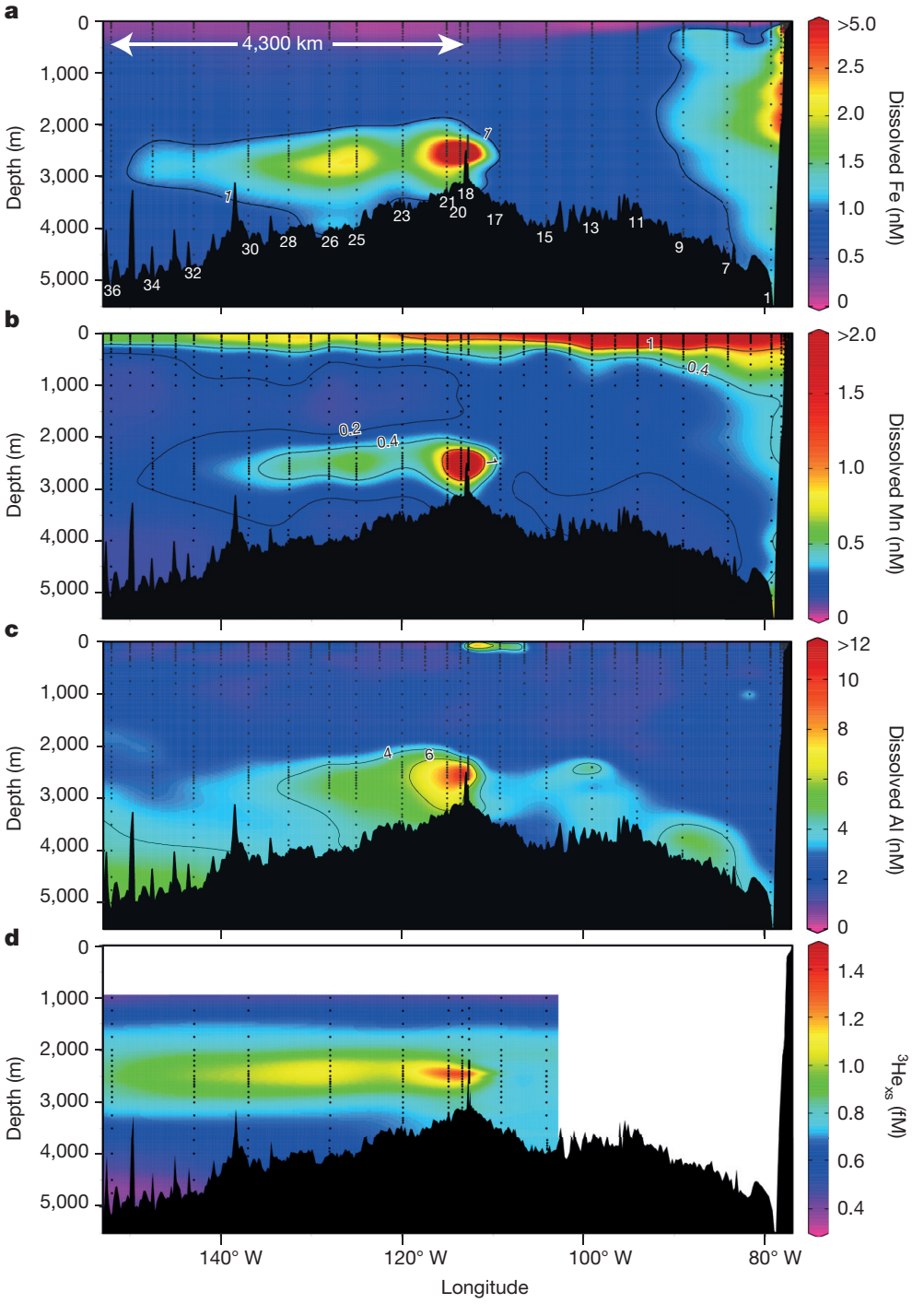
# GP16

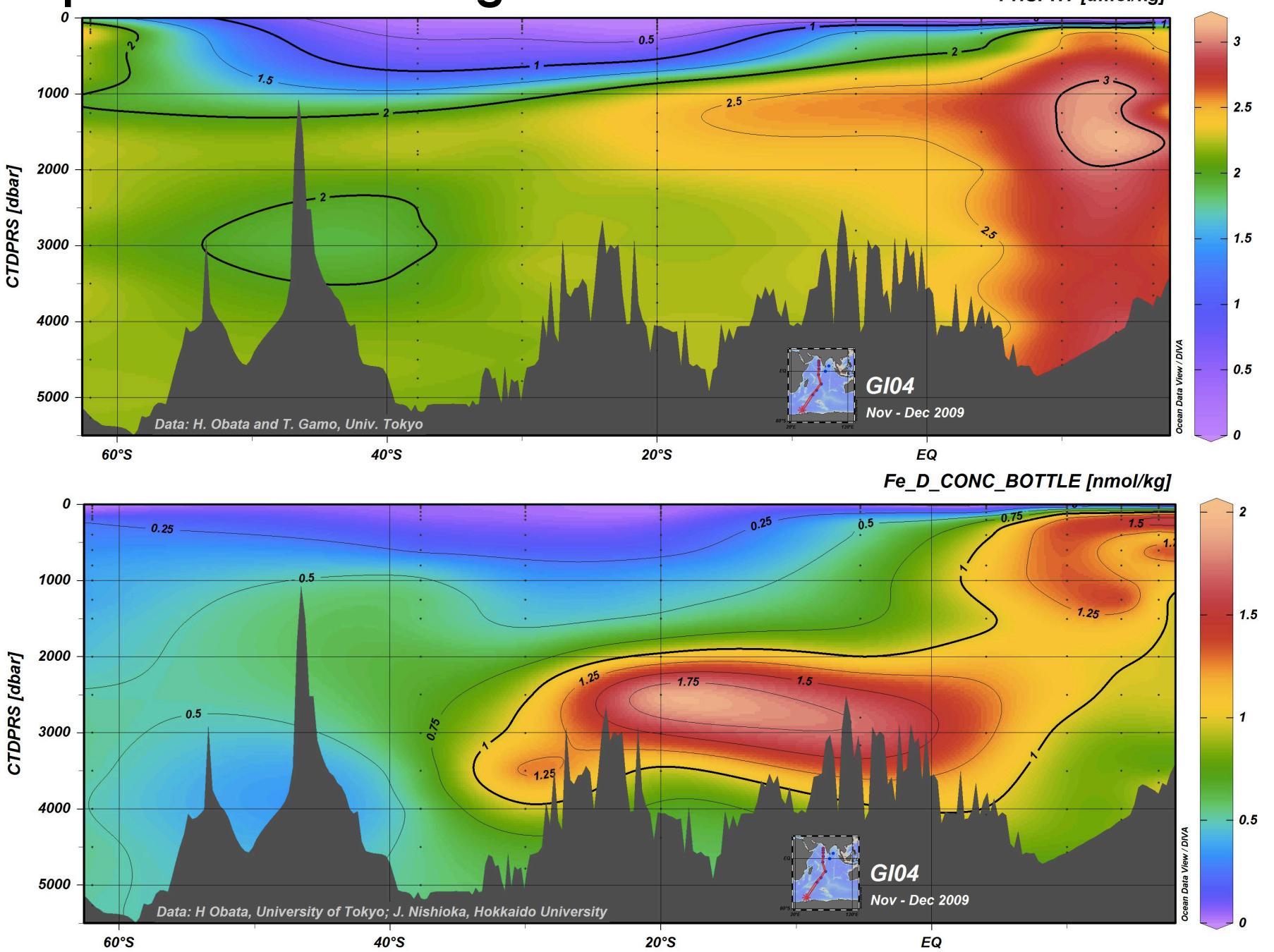
**PI: James Moffet / Chris German**
**25 Oct – 22 Dec, 2013**
**Manta – Papeete**




(Resing et al., 2015)

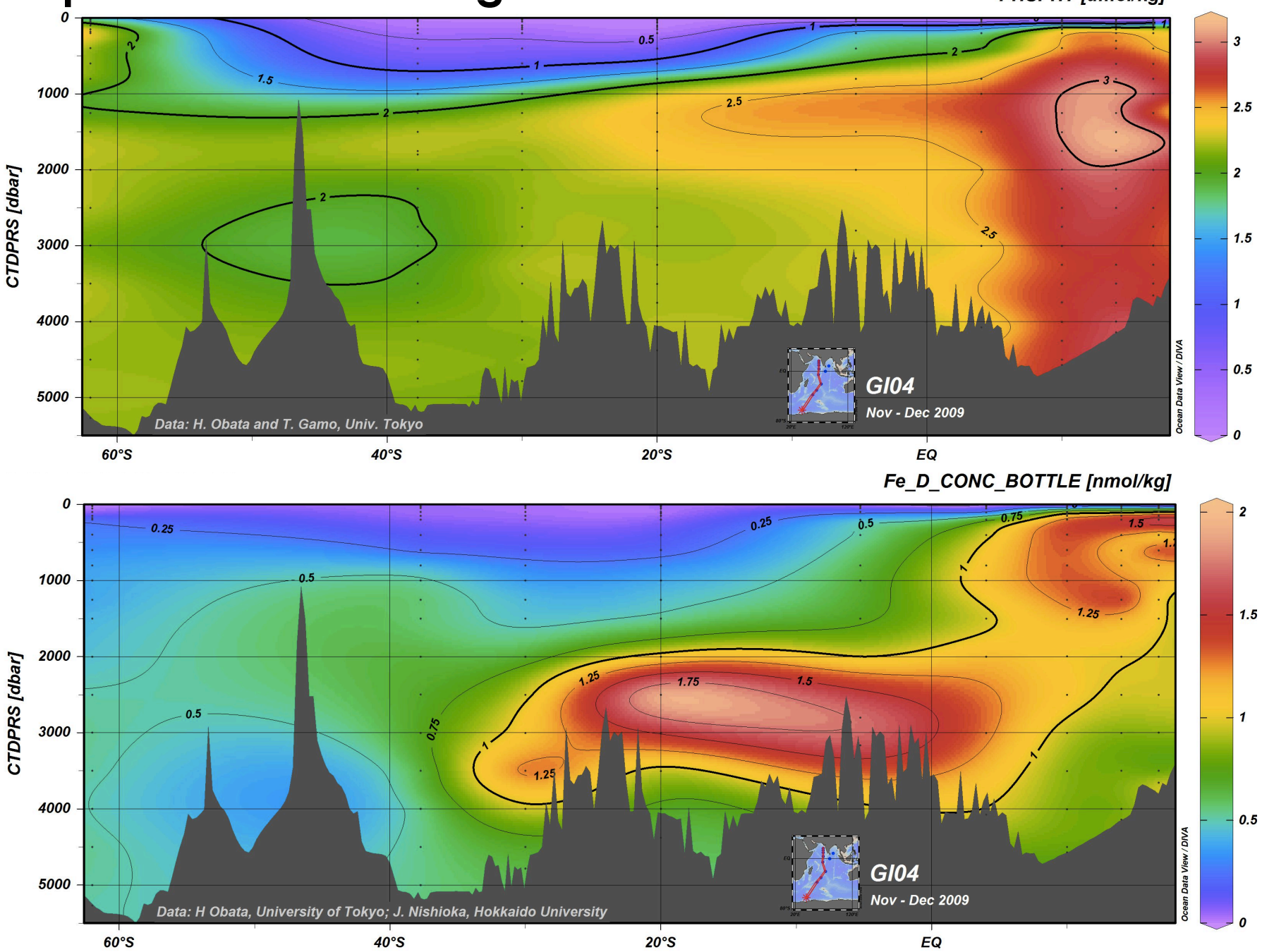
# Phosphate and Fe during GI04



# Questions as geochemists

How many are the hydrothermal vents contributing to the Fe plume?

# Phosphate and Fe during GI04



# Questions as geochemists

How many are the hydrothermal vents contributing to the Fe plume?

Is there any time-variation of the Fe plume in the Indian Ocean?

How does the Fe plume become persistent in the deep water?

# Organic ligands for Fe in the plume?

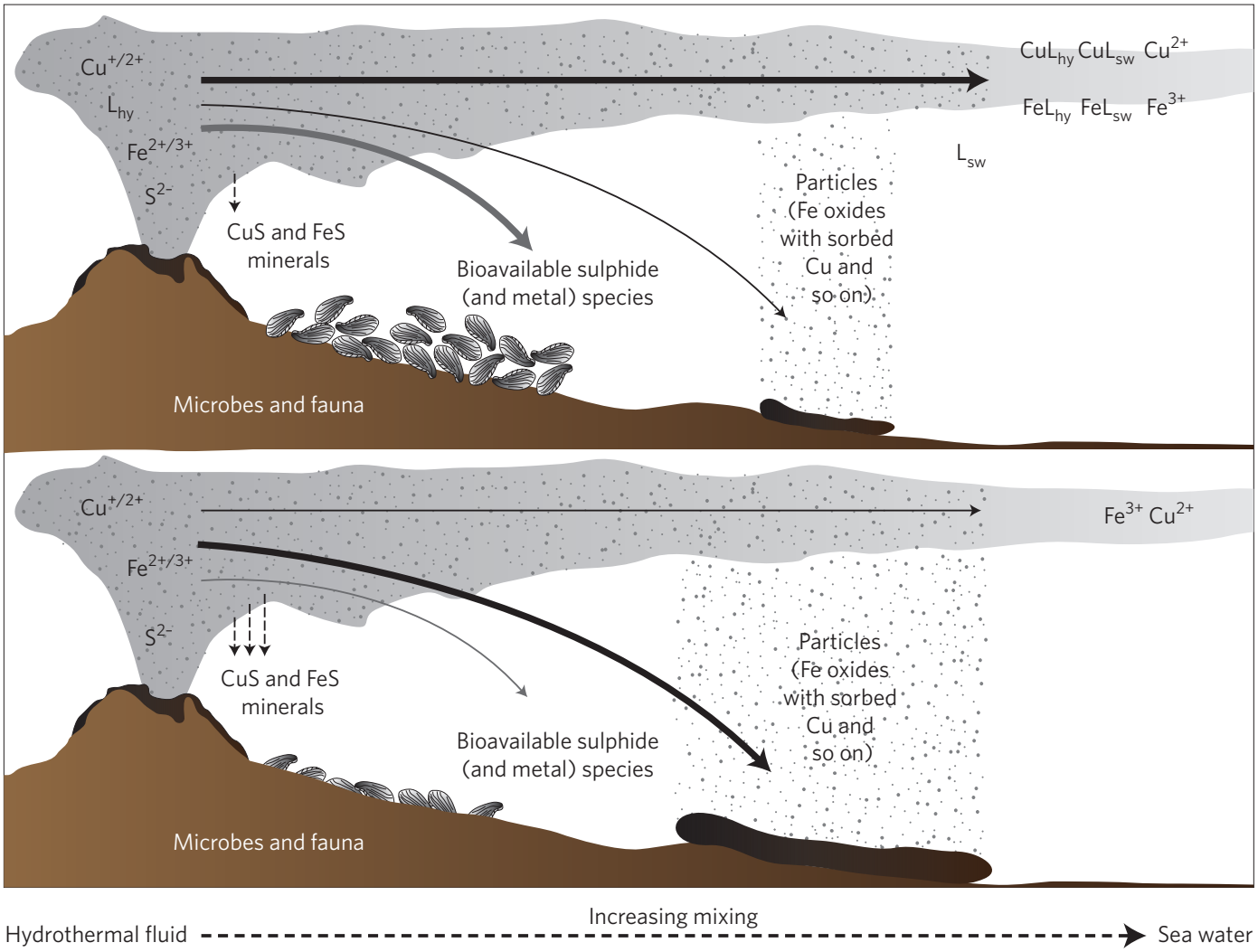



**Figure 1 | Processes in the hydrothermal fluid–seawater mixing zone.** Bottom panel: In a system with a purely inorganic metal speciation, sulphide minerals and oxide particles form principal copper and iron sinks; only negligible amounts of dissolved metals escape. Top panel: Strong copper- and iron-binding organic ligands of hydrothermal and seawater origin allow for a significant flux of dissolved metal into the ocean and leave more sulphide available for the hydrothermal biosphere. $Cu^{+/2+}$ and $Fe^{2+/3+}$ represent all inorganic copper and iron species and $S^{2-}$ all sulphide species in the fluid; $L_{hy}$ represents all copper- and iron-binding organic ligands of hydrothermal origin, and $L_{sw}$ ligands in sea water.

(Sander and Koschinsky, 2011).

# Pyrite nanoparticles in the plume?

Fe(II) is combined with acid-volatile sulphide (AVS) in the hydrothermal plume, and **pyrite nanoparticles** are formed.

↓

The pyrite nanoparticles might be slowly oxidized, and slowly scavenged in the plume.

(Yucel et al., 2011)

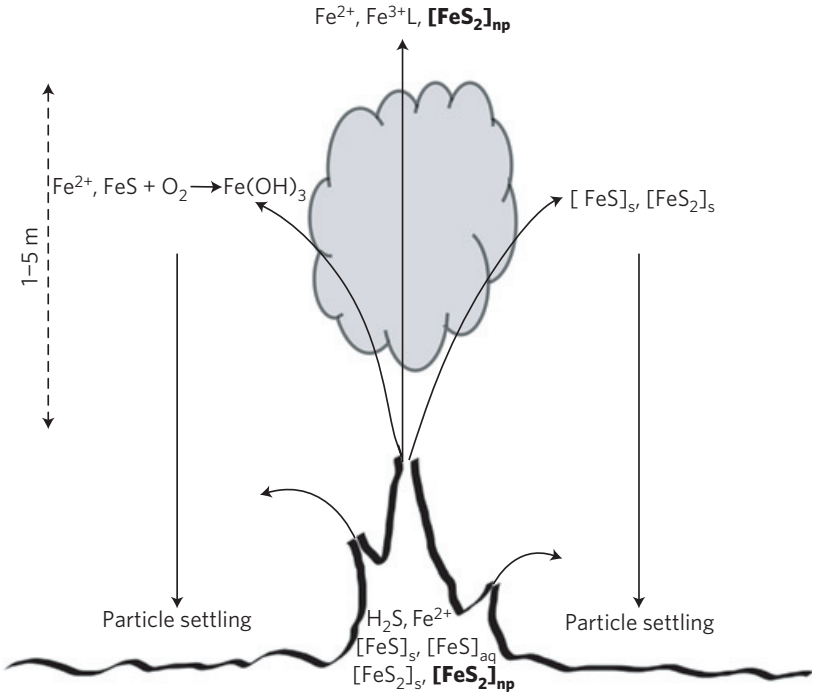
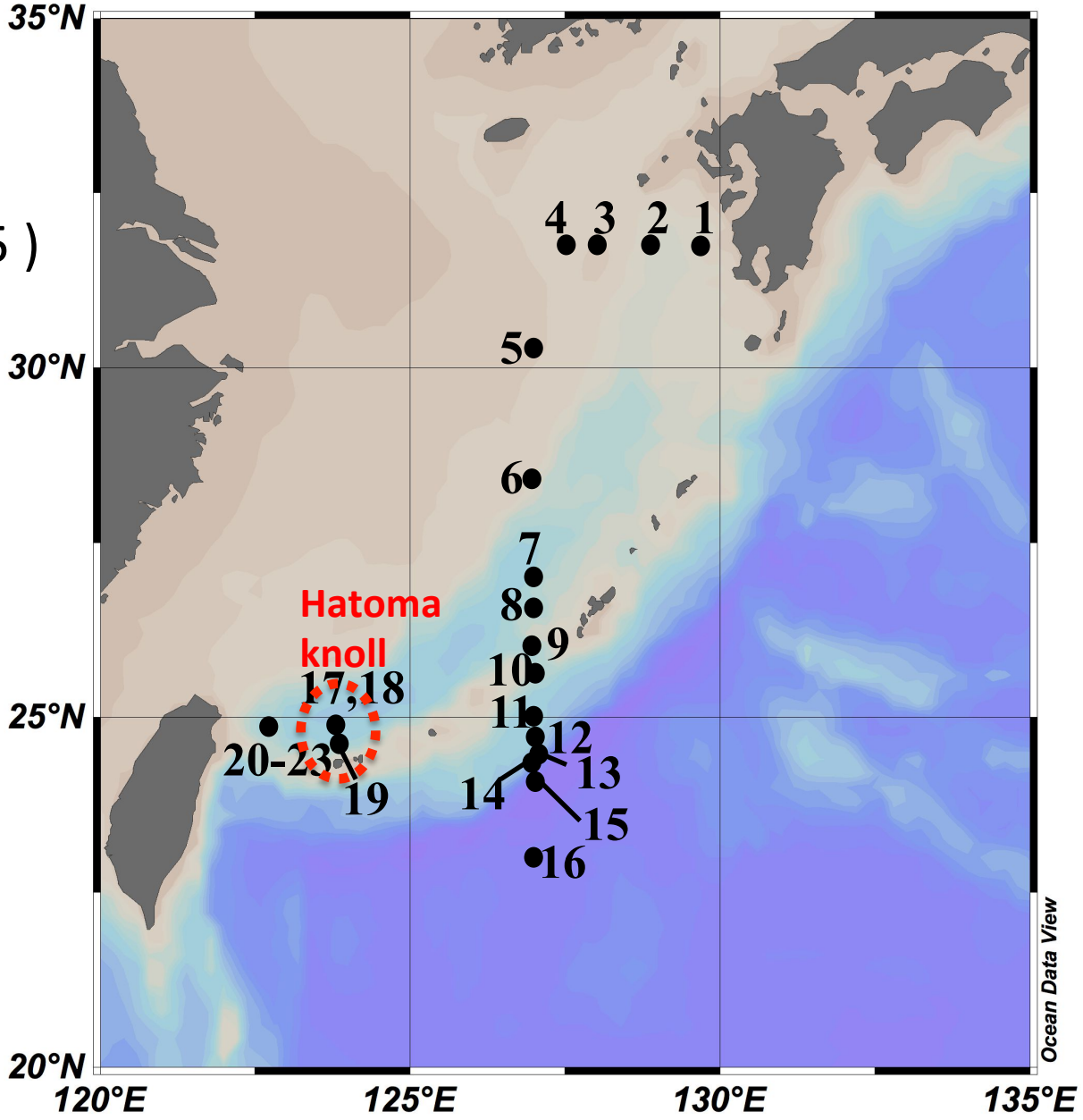



**Figure 3 | Pyrite nanoparticles as a previously unrecognized source of iron to the deep ocean.** On mixing of the vent fluid with cold, oxic seawater, Fe precipitates primarily as $Fe(OH)_3$ and polymetallic sulphides (the grey cloud represents these precipitates). Pyrite nanoparticles survive the mass precipitation taking place 1–5 m above a chimney and contribute to the iron inventory of the deep ocean. After leaving the discharge zone, the vent-derived iron can exist as Fe(II), organic Fe(III) complexes ('L' stands for organic ligands) and nanoparticle Fe(II) in the form of pyrite nanocrystals, denoted as $[FeS_2]_{np}$.

# Hydrothermal area in Okinawa Trough

R.V. Shinsei-maru
KS-15-6 cruise
(June 25 – July 07, 2015 )



# After the section studies….

**Detailed section studies?**

**Time variation?**

**Process studies?**