Hydrothermal formation of iron-oxyhydroxide chimney mounds in a shallow semi-enclosed bay at Satsuma Iwo-Jima Island, Kagoshima, Japan

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TABLE 1. MAJOR AND MINOR ELEMENTAL COMPOSITIONS OF THE IRON MOUND SAMPLE

Sample No	layer	Major Elements (mass %)															
		SiO_2	Fe_2O_3*	H_2O	Al_2O_3	Na_2O	CaO	P_2O_5	TiO_2	MnO	MgO	K_2O	LOI	Total	SiO_2/Al_2O_3	Fe/Ti	Al/(AL+Fe+Mn+Na+K+Ca)
201204CHB2	Hard	39.60	41.91	11.1	0.84	1.31	0.41	0.33	0.15	0.11	0.66	0.28	1.46	98.18	47	279	0.02
	Soft	39.56	42.84	10.3	0.67	1.29	0.4	0.34	0.15	0.12	0.66	0.28	1.29	97.91	59	286	0.01
201204CHB3	Hard	13.74	68.34	12	0.07	1.3	0.24	0.07	0.03	0.2	0.68	0.13	1.30	98.09	196	2278	0.00
	Soft	13.65	68.11	12.3	0.13	1.27	0.23	0.07	0.04	0.2	0.67	0.13	1.56	98.37	105	1703	0.00
200809CHB1	Hard	38.22	46.3	10.9	0.43	0.58	0.25	0.09	0.05	0.08	0.43	0.13	0.98	98.45	89	926	0.01
	Soft	50.31	34.51	9.4	0.46	0.99	0.27	0.15	0.09	0.06	0.5	0.2	1.11	98.05	109	383	0.01
200709CHB1	Hard	15.73	68.03	11.8	0.24	0.51	0.23	0.06	0.02	0.48	0.55	0.09	1.26	99.01	66	3402	0.00
	Soft	26.74	52.66	12.6	0.52	1.43	0.33	0.23	0.08	0.29	0.8	0.23	1.20	97.09	51	658	0.01
AVERAGE	Hard	26.82	56.15	11.46	0.40	0.93	0.28	0.14	0.06	0.22	0.58	0.16	1.25	98.43	68	898	0.01
	Soft	32.57	49.53	11.15	0.45	1.25	0.31	0.20	0.09	0.17	0.66	0.21	1.29	97.85	73	550	0.01
STDEV.P	Hard	12.12	12.14	0.45	0.29	0.38	0.07	0.11	0.05	0.16	0.10	0.07	0.17	26.12	42	235	0.02
	Soft	13.74	12.50	1.34	0.20	0.16	0.06	0.10	0.04	0.09	0.11	0.05	0.17	28.56	70	318	0.02

* Total ion as Fe_2O_3

Sample No	layer	Minor Elements (ppm)															
		S	V	Cr	Co	Ni	Cu	Zn	Pb	As	Mo	Rb	Sr	Ba	Y	Zr	Nb
201204CHB2	Hard	0.26	29.0	0.0	0	0	4.0	446	0	29533	36	18	87	26	11	44	4
	Soft	0.27	29.0	0.0	0	0	3.0	451	0	30483	39	15	87	23	12	45	3
201204CHB3	Hard	0.46	24.0	11.0	0	0	1.0	985	0	26298	64	11	67	0	77	0	2
	Soft	0.45	24.0	13.0	0	0	3.0	981	0	25977	64	11	65	0	76	1	5
200809CHB1	Hard	0.34	17.0	2.0	0	0	1.0	465	0	21197	44	10	43	0	17	3	4
	Soft	0.26	23.0	1.0	0	0	1.0	326	0	27294	28	15	51	19	26	27	5
200709CHB1	Hard	0.35	5.0	9.0	0	0	0.0	973	0	17681	72	6	71	0	29	0	4
	Soft	0.38	29.0	4.0	0	0	4.0	569	0	36592	46	14	85	0	35	23	5
AVERAGE	Hard	0.35	18.8	5.5	0	0	1.5	717	0	23677	54	11	67	7	34	12	4
	Soft	0.34	26.3	4.5	0	0	2.8	582	0	30087	44	14	72	11	37	24	5
STDEV.P	Hard	0.07	9.0	4.6	0	0	1.5	262	0	4562	15	4	16	11	26	19	1
	Soft	0.08	2.8	5.1	0	0	1.1	246	0	4098	13	2	15	11	24	16	1

Figure 1

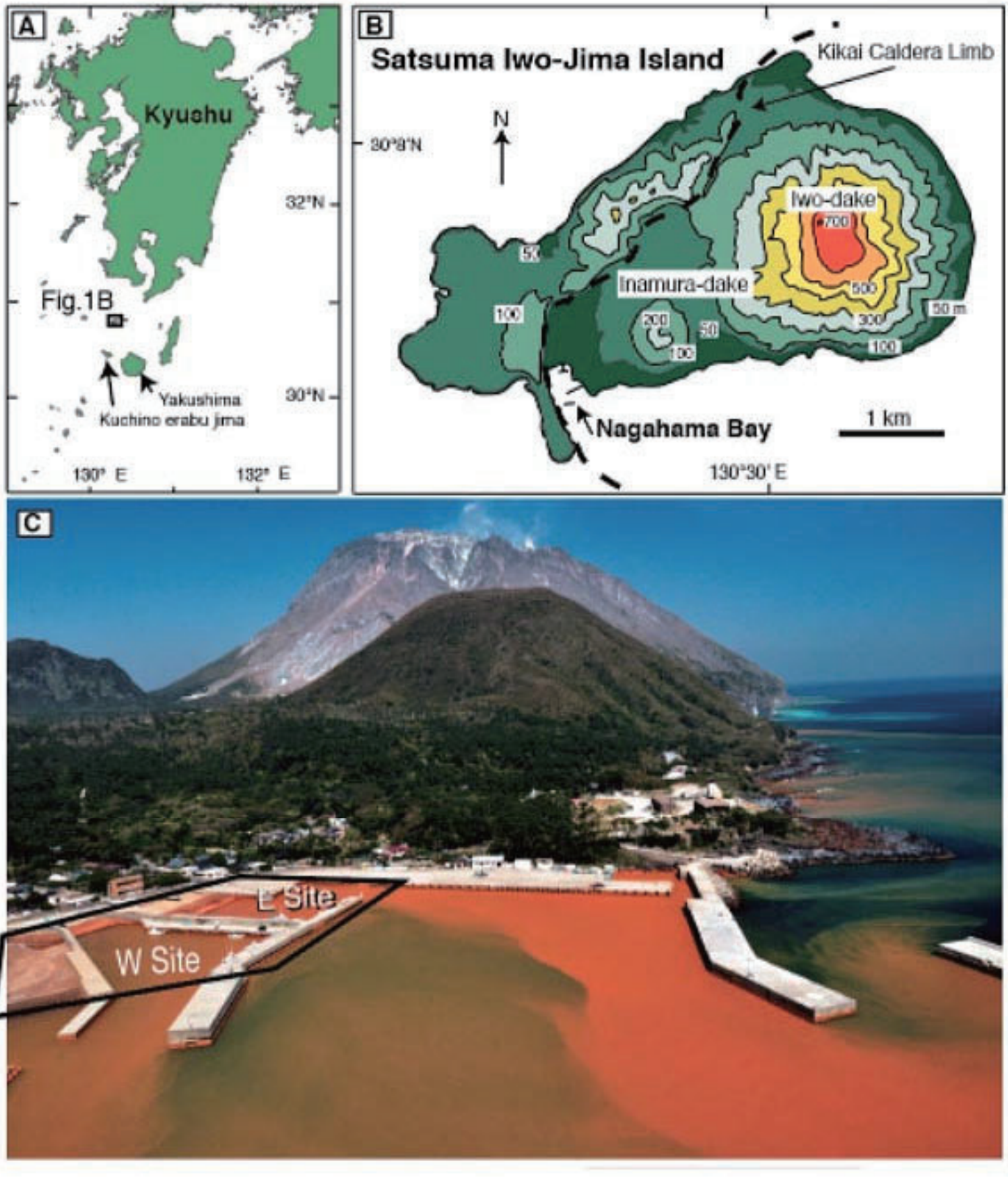

A
Kyushu
32°N
Fig.1B
Yakushima
Kuchino erabu jima
30°N
130° E
132° E
B
Satsuma Iwo-Jima Island
Kikai Caldera Limb
N
30°8'N
Iwo-dake
700
500
300
100
50 m
Inamura-dake
200
100
50
100
Nagahama Bay
1 km
130°30' E
C
E Site
W Site

Figure 2

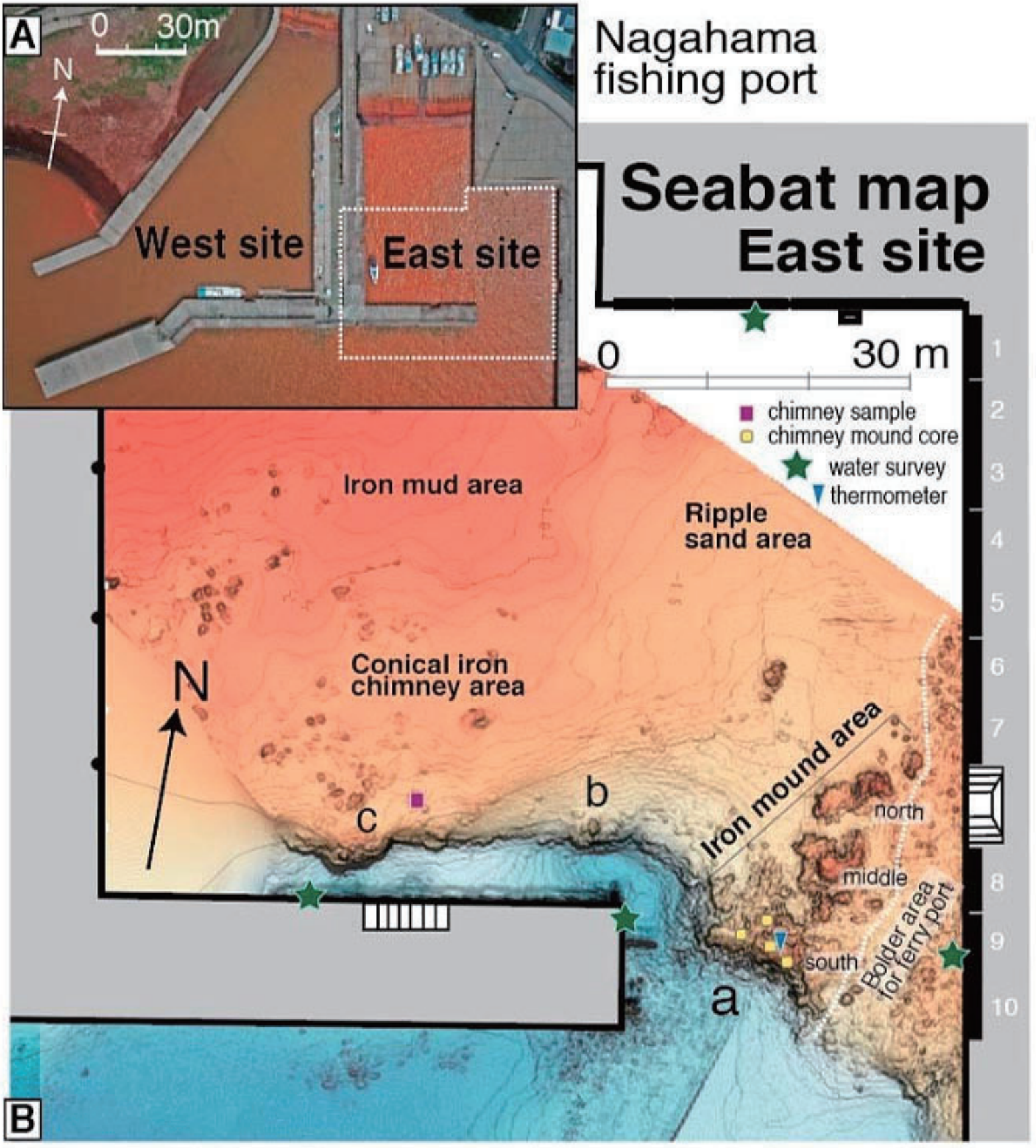

A
0 30m
N
West site
East site
Nagahama
fishing port
Seabat map
East site
0 30 m
chimney sample
chimney mound core
water survey
thermometer
Iron mud area
Ripple
sand area
Conical iron
chimney area
N
c
b
a
Iron mound area
north
middle
south
Bolder area
for ferry port
1
2
3
4
5
6
7
8
9
10
B

Figure 3

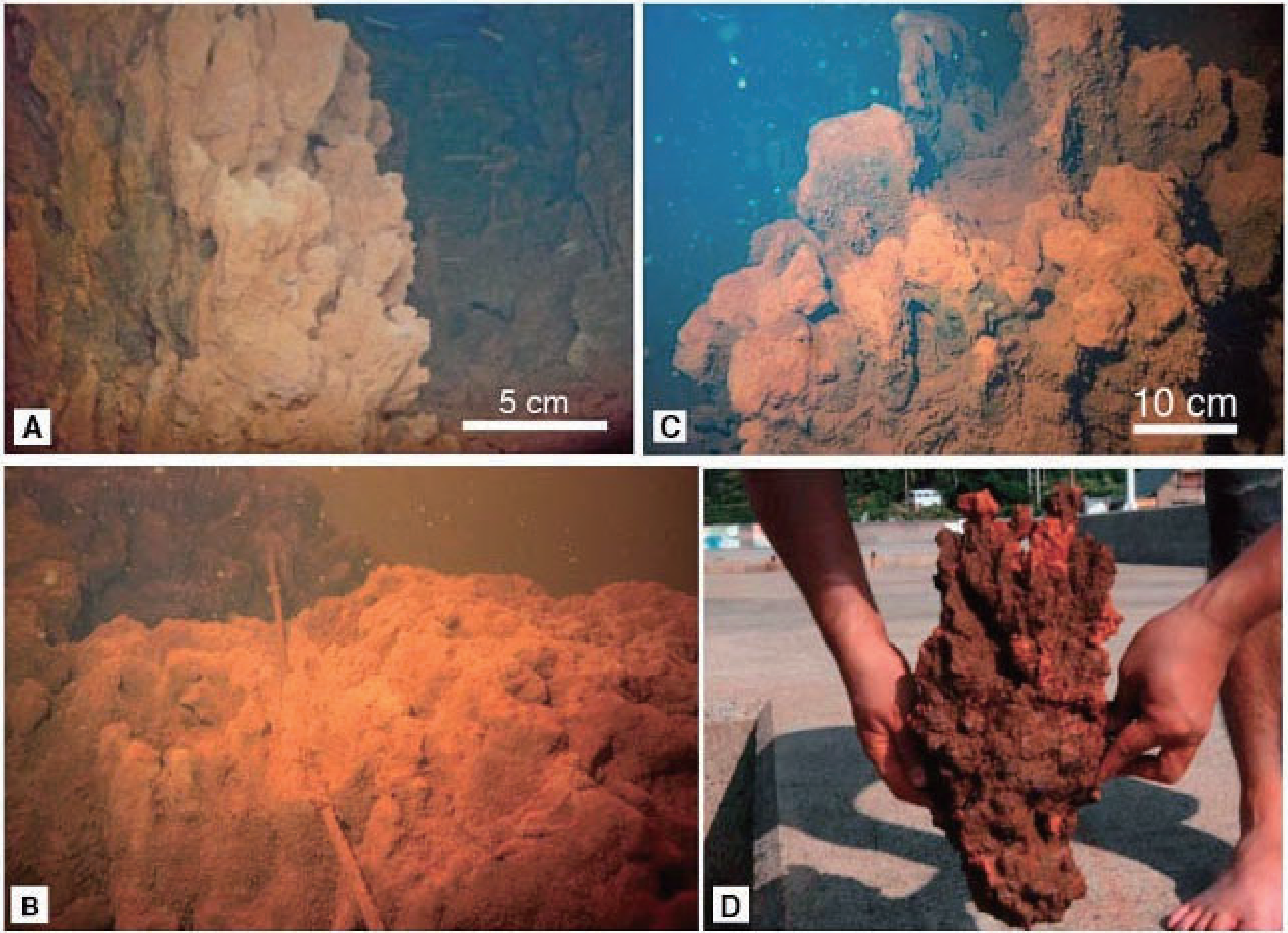


Figure4

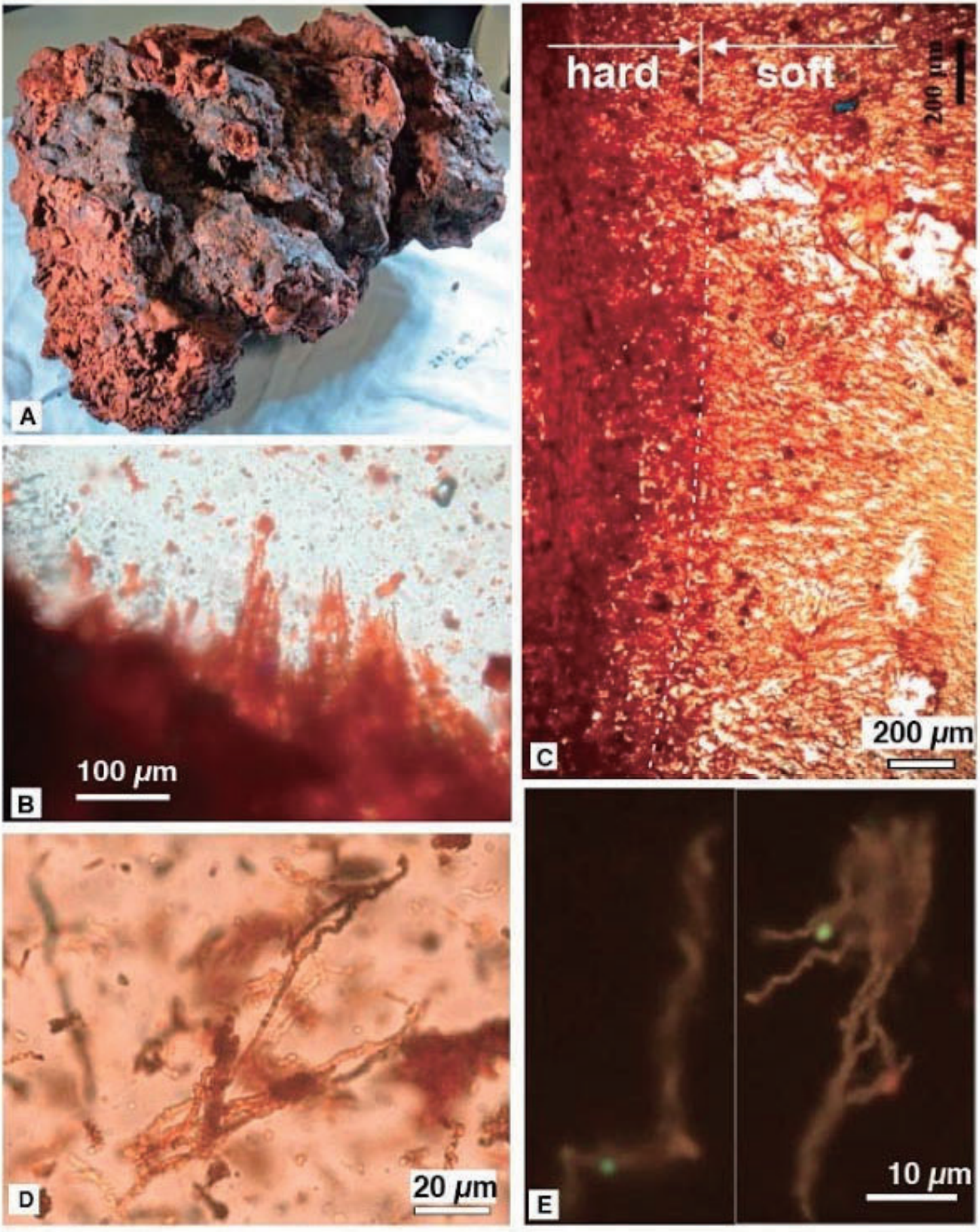


Figure 5

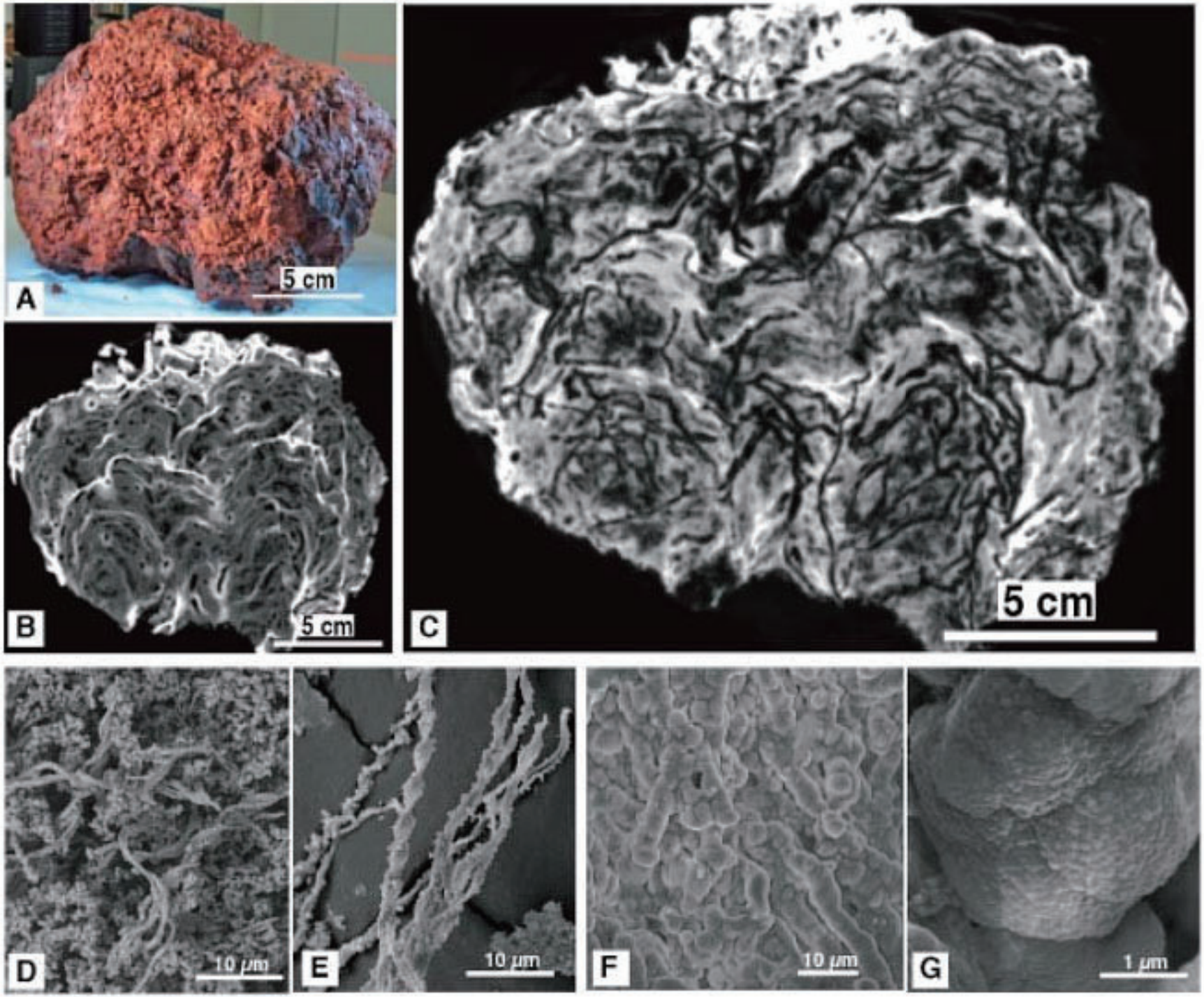


Figure 6

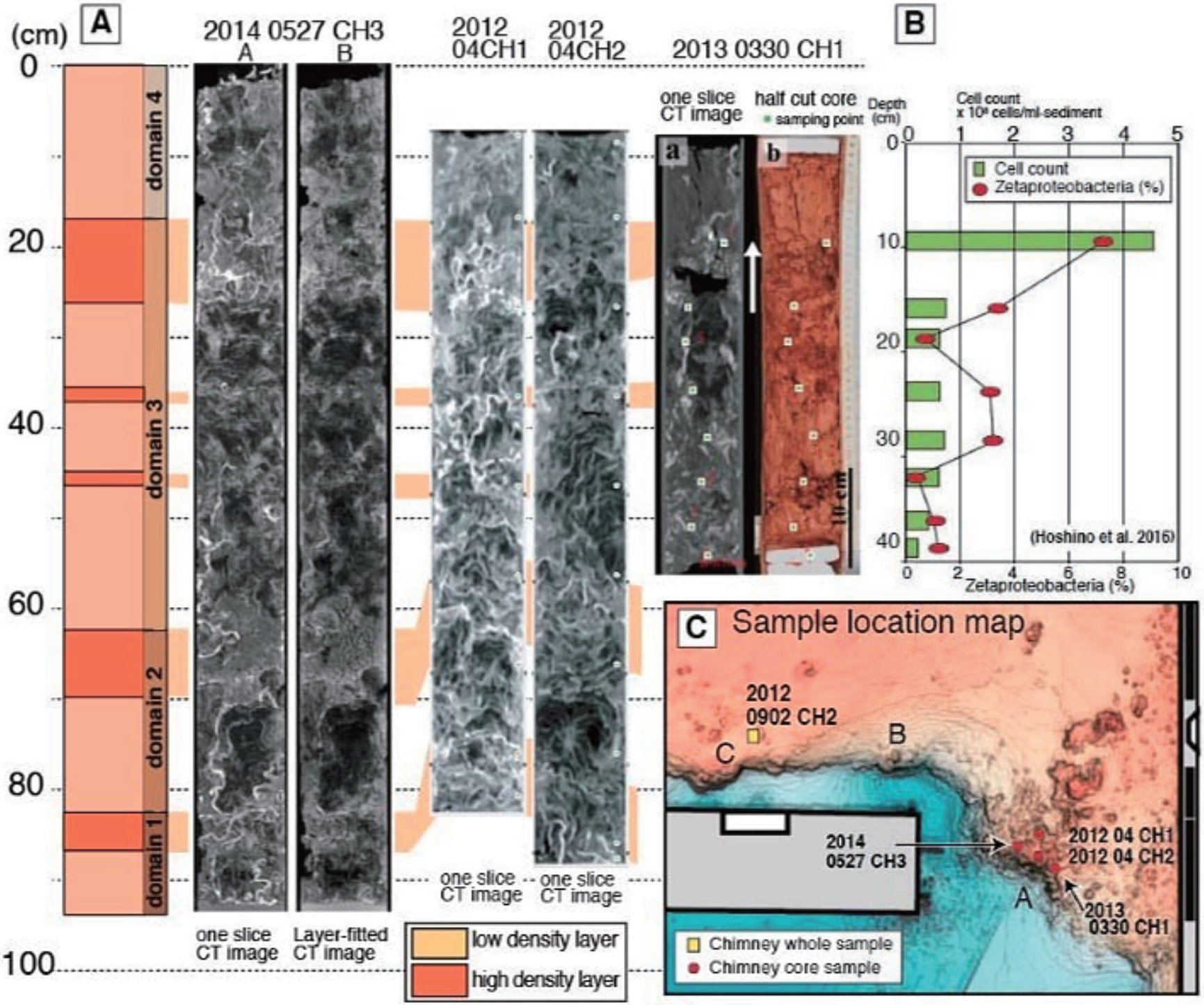

(cm)
A
2014 0527 CH3
A
B
2012
04CH1
2012
04CH2
2013 0330 CH1
B
one slice
CT image
half cut core
sampling point
Depth
(cm)
Cell count
x 10⁸ cells/ml-sediment
Cell count
Zetaproteobacteria (%)
(Hoshino et al. 2016)
Zetaproteobacteria (%)
domain 4
domain 3
domain 2
domain 1
a
b
10 cm
one slice
CT image
Layer-fitted
CT image
one slice
CT image
one slice
CT image
low density layer
high density layer
C
Sample location map
2012
0902 CH2
B
C
2014
0527 CH3
2012 04 CH1
2012 04 CH2
A
2013
0330 CH1
Chimney whole sample
Chimney core sample

Figure 7

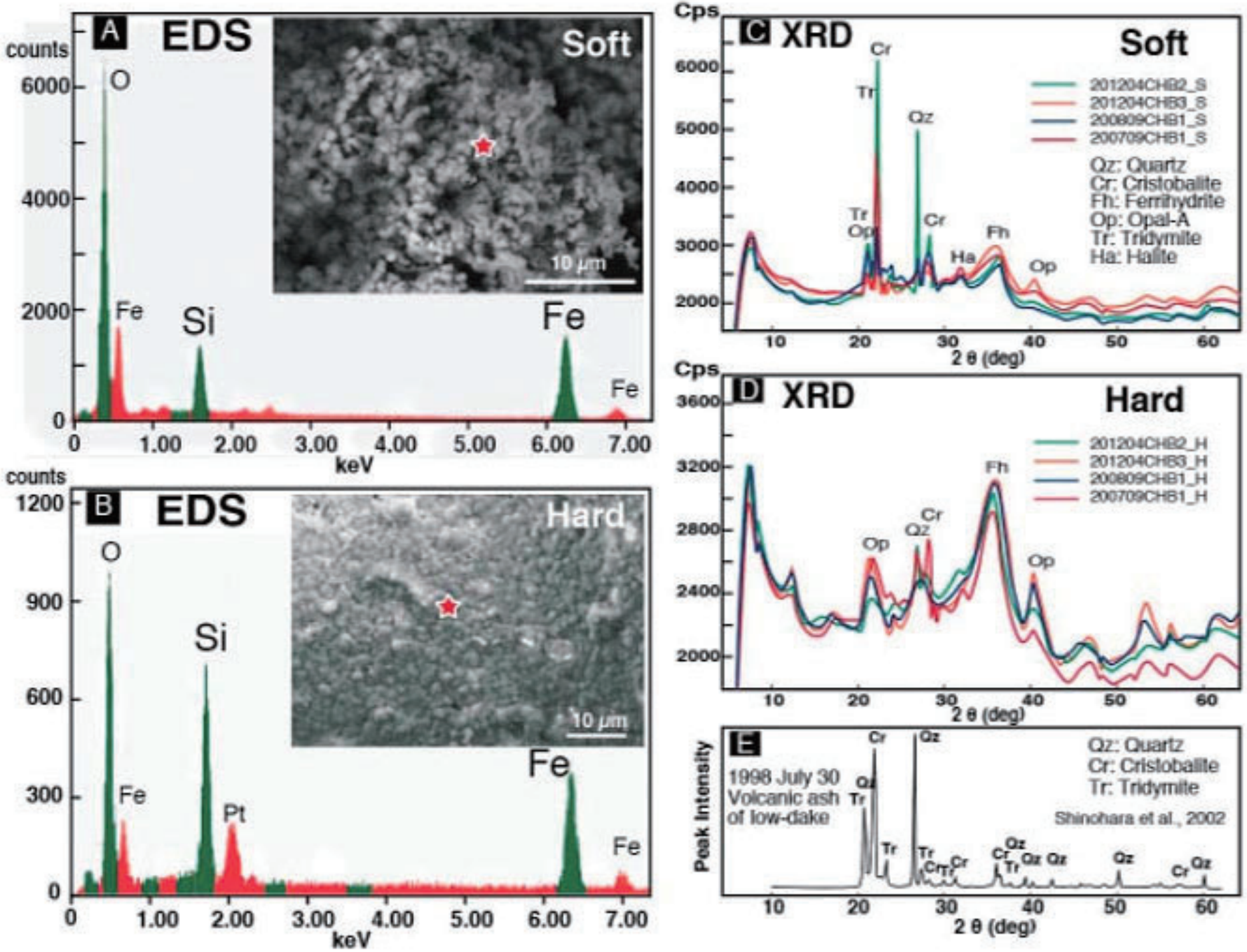

A
EDS
Soft
counts
O
Fe
Si
Fe
Fe
10 μm
keV
B
EDS
Hard
Pt
C
XRD
Soft
Cps
Cr
Tr
Qz
Op
Ha
Fh
201204CHB2_S
201204CHB3_S
200809CHB1_S
200709CHB1_S
Qz: Quartz
Cr: Cristobalite
Fh: Ferrihydrite
Op: Opal-A
Tr: Tridymite
Ha: Halite
2 θ (deg)
D
XRD
Hard
201204CHB2_H
201204CHB3_H
200809CHB1_H
200709CHB1_H
E
1998 July 30
Volcanic ash
of low-dake
Peak Intensity
Shinohara et al., 2002

Figure8

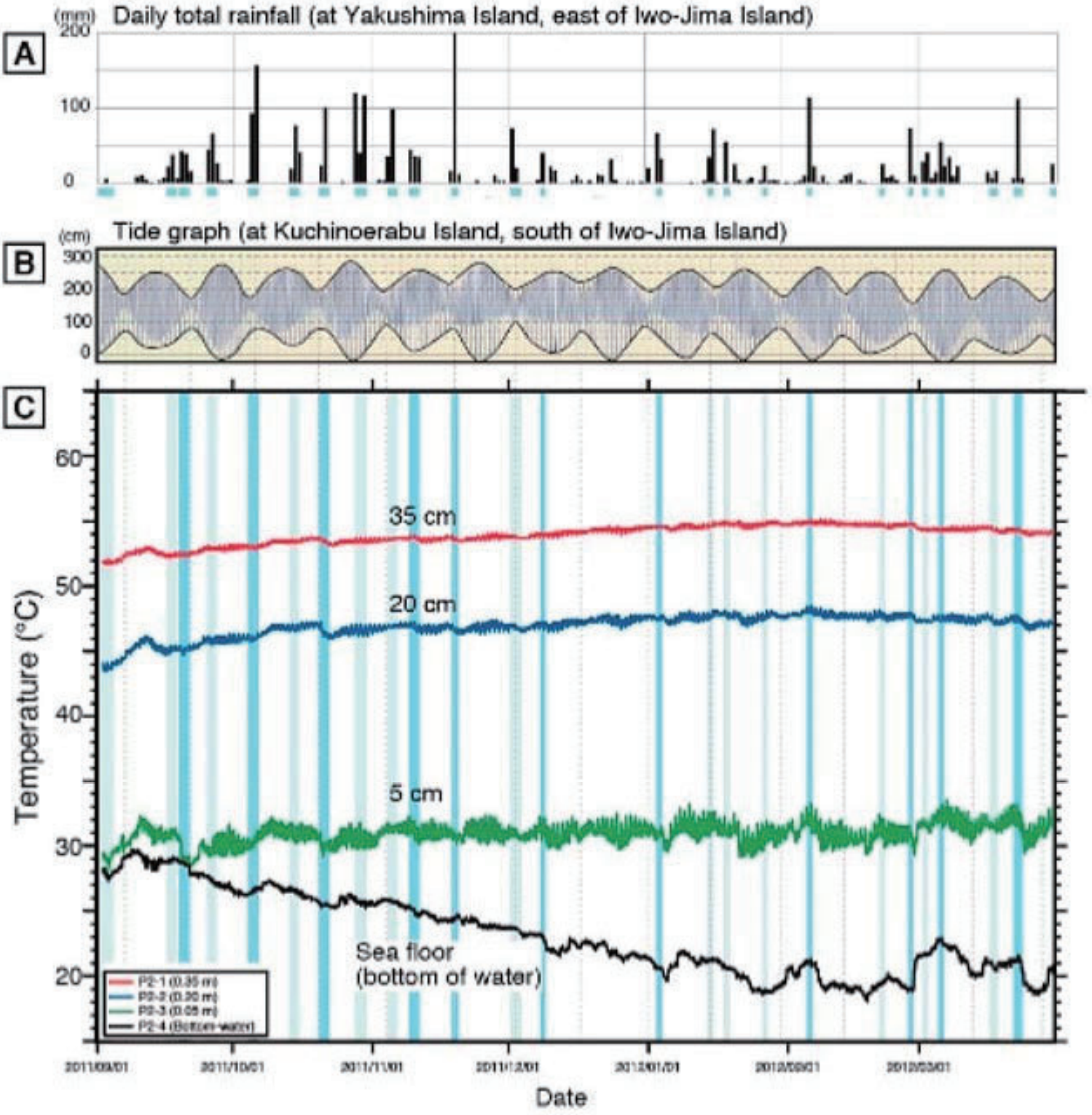

A
(mm)
Daily total rainfall (at Yakushima Island, east of Iwo-Jima Island)
200
100
0
B
(cm)
Tide graph (at Kuchinoerabu Island, south of Iwo-Jima Island)
300
200
100
0
C
60
50
40
30
20
Temperature (°C)
35 cm
20 cm
5 cm
Sea floor
(bottom of water)
Date

Figure9

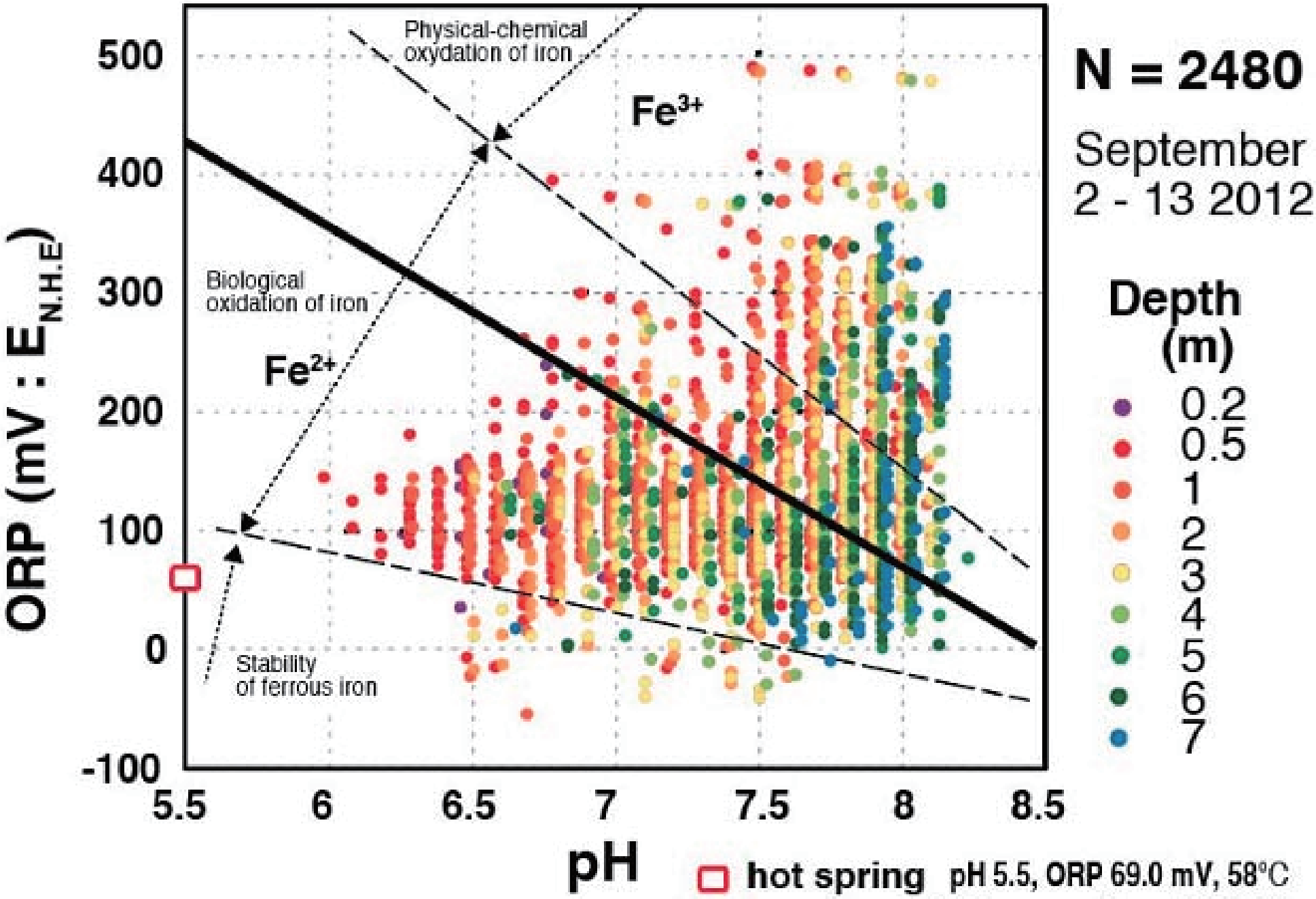

Physical-chemical
oxydation of iron
Fe3+
Biological
oxidation of iron
Fe2+
Stability
of ferrous iron
N = 2480
September
2 - 13 2012
Depth
(m)
0.2
0.5
1
2
3
4
5
6
7
ORP (mV : E N.H.E)
500
400
300
200
100
0
-100
5.5
6
6.5
7
7.5
8
8.5
pH
hot spring pH 5.5, ORP 69.0 mV, 58°C
Shikaura and Tazaki (2001)

Figure10

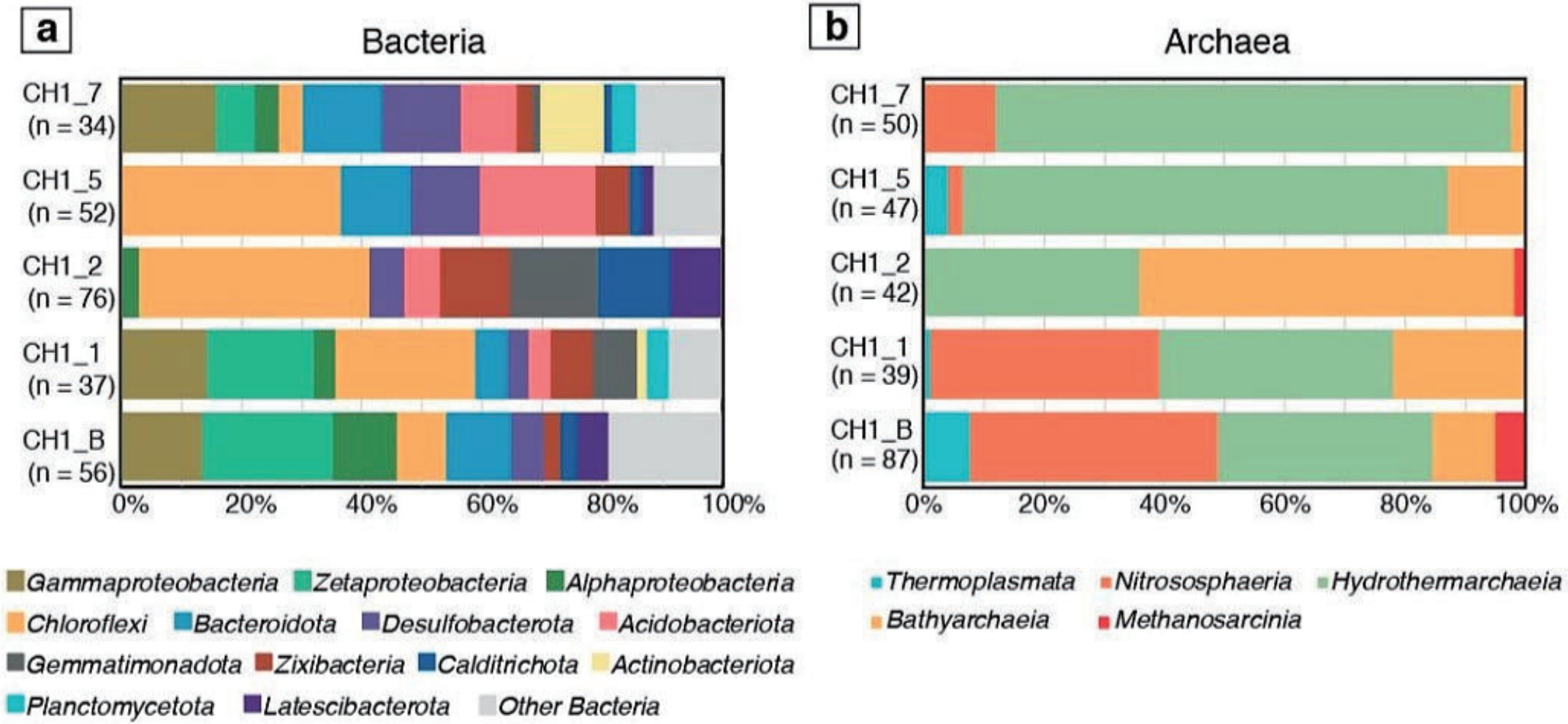
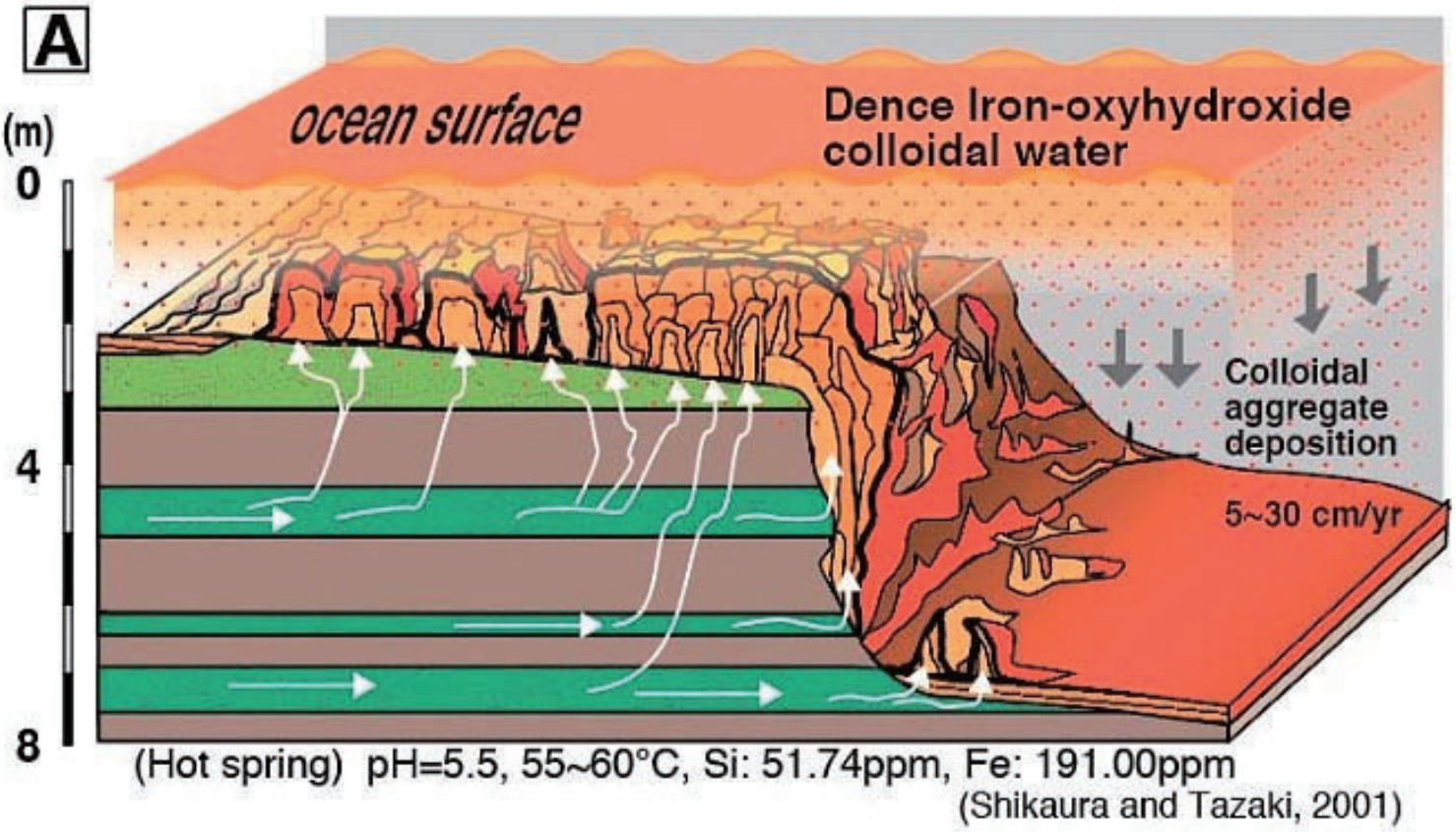
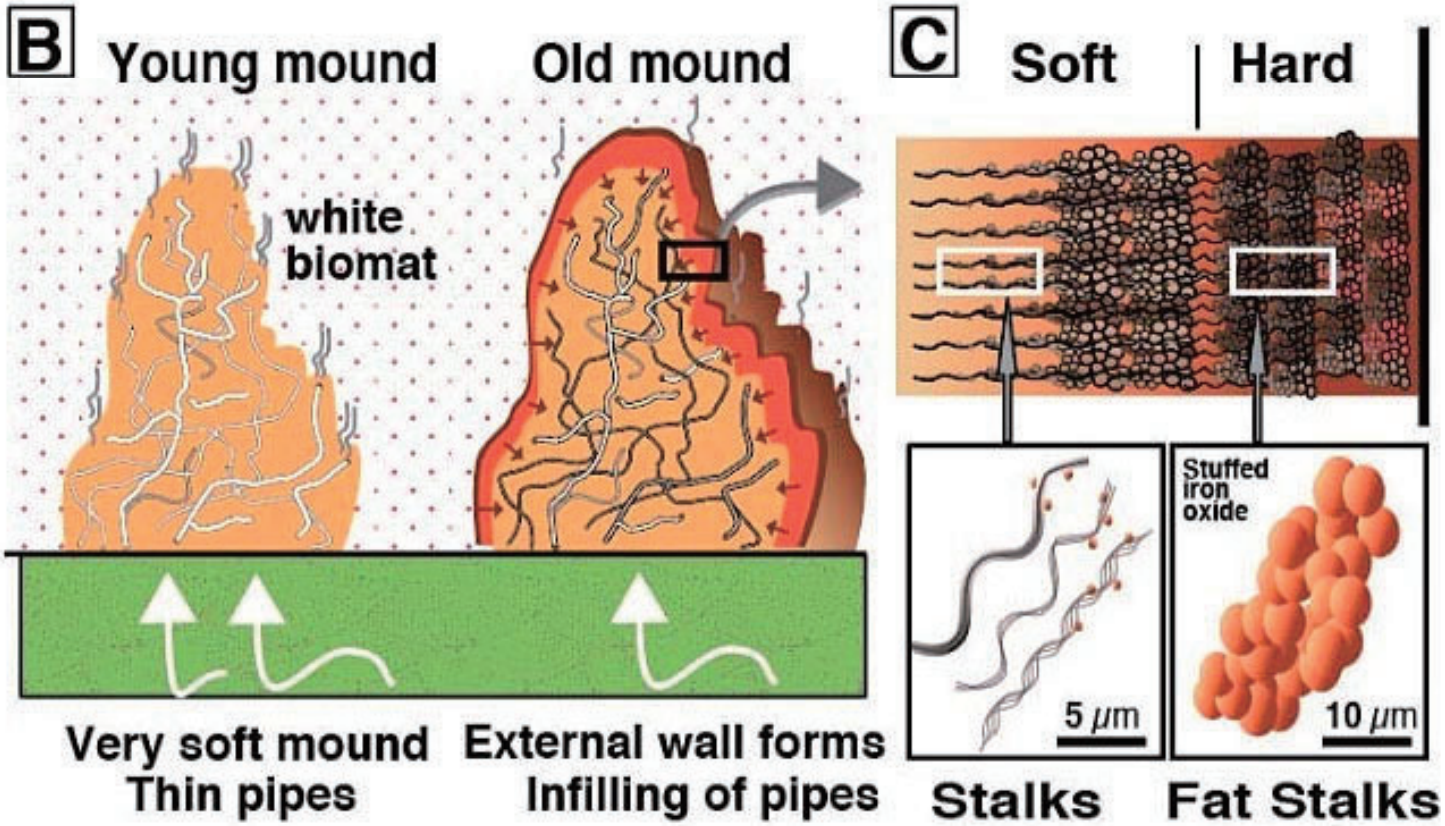

a
Bacteria
CH1_7 (n = 34)
CH1_5 (n = 52)
CH1_2 (n = 76)
CH1_1 (n = 37)
CH1_B (n = 56)
0%
20%
40%
60%
80%
100%
b
Archaea
CH1_7 (n = 50)
CH1_5 (n = 47)
CH1_2 (n = 42)
CH1_1 (n = 39)
CH1_B (n = 87)
0%
20%
40%
60%
80%
100%
Gammaproteobacteria
Zetaproteobacteria
Alphaproteobacteria
Chloroflexi
Bacteroidota
Desulfobacterota
Acidobacteriota
Gemmatimonadota
Zixibacteria
Calditrichota
Actinobacteriota
Planctomycetota
Latescibacterota
Other Bacteria
Thermoplasmata
Nitrososphaeria
Hydrothermarchaeia
Bathyarchaeia
Methanosarcinia

Figure11


A
(m)
0
4
8
ocean surface
Dence Iron-oxyhydroxide
colloidal water
Colloidal
aggregate
deposition
5~30 cm/yr
(Hot spring) pH=5.5, 55~60°C, Si: 51.74ppm, Fe: 191.00ppm
(Shikaura and Tazaki, 2001)


B
Young mound
Old mound
white
biomat
Very soft mound
Thin pipes
External wall forms
Infilling of pipes
C
Soft
Hard
Stuffed
iron
oxide
5 μm
10 μm
Stalks
Fat Stalks

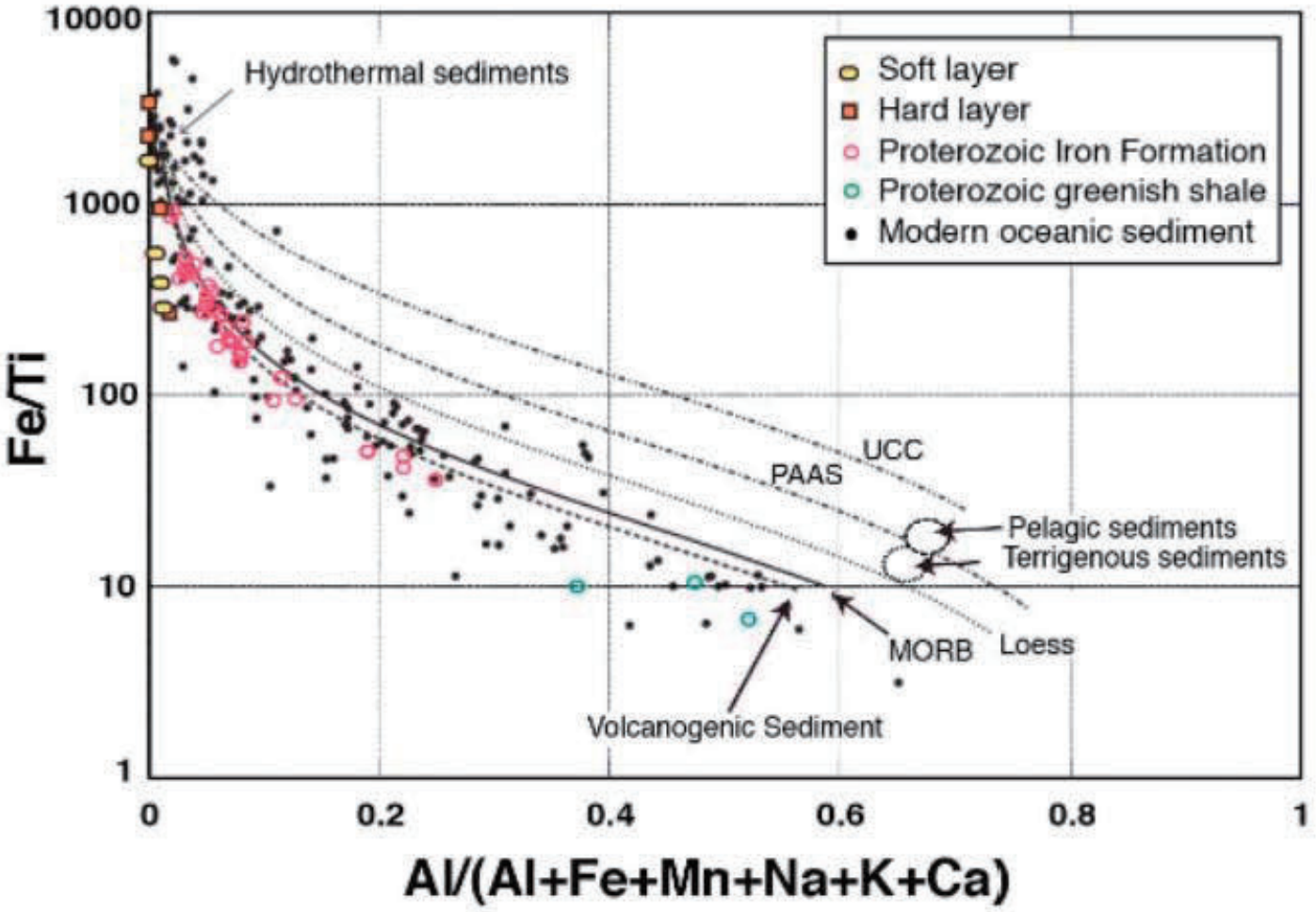


Figure S1. (Supplemental Material)
Plot of Fe/Ti versus Al/(Al+Fe+Mn+Na+K+Ca) after Böstrom (1970), Cox et al. (2013), and Abd El-Rahman et al. (2019). End-member compositions of hydrothermal precipitates are from Marchig and Gundlach (1982). The line denoting the upper continental crust (UCC) is from Cribb and Barton (1996); the lines for shale (PAAS), mid-ocean ridge basalt (MORB), and volcanogenic sediment are from Taylor and McLennan (1985); and the line denoting loess is from Taylor et al. (1983).