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# XIII. MINOR CHEMICAL COMPOSITION OF DEEP-SEA SEDIMENTS FROM THE GH80–5 AREA IN THE CENTRAL PACIFIC BASIN

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## Introduction

The moisture content and the minor elements, such as Mn, Fe, Co, Ni, Cu, Zn and Pb, were determined for 109 sediment samples from the GH80–5 area, in order to elucidate the origin of manganese nodules. The total 109 sediment samples consist of 22 surface sediment samples and 87 core segment samples, whose maximum depth below the bottom surface attains to about 8 m in the longest core. From the results, general distribution of metal contents and the correlations among each element are described for surficial and core segment samples.

## Sample preparation and analytical method

The methods of sample preparation and analysis were the same as those in our preceding work (MITA *et al.*, 1982). The outline of them are as follows.

The sediment samples which contain sea water were dried in air enough. After grinding, the sample was weighed out into platinum dish and then mixed with nitric acid, hydrofluoric acid and perchloric acid. The dish was heated to dryness. The salts were dissolved with hydrochloric acid and the acidity of HCl was adjusted to 0.3 N. Then the contents of Mn, Fe, Co, Ni, Cu, Zn and Pb in the samples were determined by atomic absorption spectrophotometry. The moisture contents at 110°C were determined for another aliquot.

## Results and discussions

The dry basis contents of Mn, Fe, Co, Ni, Cu, Zn and Pb in the 109 samples are shown in Table XIII–1. The averages, minimums, maximums and standard deviations for each element in all samples and in three sample groups based on the sediment facies, i.e. siliceous fossil rich clay (SRC), pelegic clay (PC) and zeolitic clay (ZC), are shown in Table XIII–2.

On previous cruise, GH80–1, it has been noted that the sediment in the Penrhyn Basin is extraordinary rich in metal elements, such as those mentioned above. Maximum contents are 2.22% for Mn, 8.81% for Fe and 1134 ppm for Cu, for examples (MITA *et al.*, 1982). On this cruise, however, maximum contents of them are 1.74% (Mn), 5.9% (Fe) and 903 ppm (Cu).

Table XIII-1 Minor chemical composition of bottom sediments in the GH80-5 area (in dry basis)

| Analysis No. | Sample No. | Sediment Type | Mn % | Fe % | Co ppm | Ni ppm | Cu ppm | Zn ppm | Pb ppm |
|---|---|---|---|---|---|---|---|---|---|
| 1 | P194 (1)77- 82 | SRC | 0.56 | 4.91 | 105 | 120 | 429 | 539 | 62 |
| 2 | P194 (2)25- 30 | PC | 0.72 | 5.16 | 120 | 184 | 465 | 643 | 47 |
| 3 | P194 (2)75- 80 | PC | 0.74 | 5.38 | 128 | 181 | 517 | 506 | 53 |
| 4 | P194 (3)25- 30 | PC | 0.87 | 5.43 | 130 | 287 | 611 | 323 | 50 |
| 5 | P194 (3)75- 80 | PC | 0.95 | 4.66 | 152 | 399 | 846 | 387 | 52 |
| 6 | P194 (4)25- 30 | ZC | 0.80 | 4.19 | 151 | 325 | 797 | 231 | 45 |
| 7 | P194 (4)75- 80 | ZC | 0.87 | 4.17 | 134 | 260 | 878 | 317 | 62 |
| 8 | P194 (5)25- 30 | ZC | 0.91 | 4.57 | 148 | 267 | 903 | 235 | 53 |
| 9 | P194 (5)75- 80 | ZC | 1.08 | 5.16 | 166 | 306 | 838 | 423 | 59 |
| 10 | P194 (6)25- 30 | ZC | 1.14 | 4.08 | 119 | 249 | 703 | 263 | 55 |
| 11 | P194 (6)75- 80 | ZC | 1.11 | 3.88 | 122 | 251 | 709 | 272 | 51 |
| 12 | P194 (7)25- 30 | ZC | 1.18 | 4.10 | 128 | 277 | 286 | 252 | 46 |
| 13 | P194 (7)75- 80 | ZC | 1.38 | 4.94 | 186 | 399 | 724 | 249 | 53 |
| 14 | P194 (8)25- 30 | ZC | 0.47 | 1.83 | 42 | 55 | 299 | 87 | 18 |
| 15 | P194 (8)83- 88 | SO | 0.95 | 3.71 | 99 | 223 | 650 | 217 | 38 |
| 16 | P195 (2)18- 23 | SRC | 1.07 | 3.83 | 112 | 225 | 610 | 179 | 39 |
| 17 | P195 (2)65- 70 | ZC | 1.07 | 4.54 | 121 | 246 | 493 | 197 | 48 |
| 18 | P195 (3)15- 20 | ZC | 0.91 | 4.18 | 109 | 176 | 459 | 198 | 58 |
| 19 | P195 (3)65- 70 | ZC | 1.02 | 4.08 | 111 | 188 | 506 | 192 | 41 |
| 20 | P195 (4)15- 20 | ZC | 1.02 | 4.05 | 115 | 185 | 511 | 181 | 37 |
| 21 | P195 (4)65- 70 | ZC | 0.99 | 4.35 | 111 | 207 | 505 | 182 | 50 |
| 22 | P195 (5)15- 20 | ZC | 1.02 | 4.21 | 122 | 265 | 536 | 222 | 38 |
| 23 | P195 (5)65- 70 | ZC | 1.04 | 4.40 | 122 | 268 | 574 | 201 | 37 |
| 24 | P195 (6)15- 20 | ZC | 1.01 | 4.43 | 113 | 216 | 526 | 218 | 43 |
| 25 | P195 (6)65- 70 | ZC | 1.01 | 4.50 | 105 | 213 | 507 | 186 | 36 |
| 26 | P195 (7)15- 20 | ZC | 0.98 | 4.57 | 102 | 220 | 442 | 192 | 37 |
| 27 | P195 (7)65- 70 | ZC | 1.02 | 4.44 | 108 | 219 | 461 | 196 | 45 |
| 28 | P195 (8)15- 20 | ZC | 0.96 | 4.24 | 111 | 196 | 463 | 186 | 38 |
| 29 | P195 (8)65- 70 | ZC | 0.99 | 4.36 | 118 | 195 | 500 | 189 | 31 |
| 30 | P198 (1)93- 98 | SRC | 0.56 | 4.69 | 99 | 136 | 383 | 140 | 38 |
| 31 | P198 (2)38- 43 | PC | 0.64 | 4.86 | 107 | 161 | 414 | 194 | 37 |
| 32 | P198 (2)88- 93 | PC | 0.66 | 4.95 | 108 | 155 | 402 | 193 | 36 |
| 33 | P198 (3)38- 43 | PC | 0.69 | 5.12 | 114 | 162 | 482 | 147 | 47 |
| 34 | P198 (3)88- 93 | PC | 0.67 | 5.01 | 106 | 162 | 439 | 140 | 52 |
| 35 | P198 (4)38- 43 | PC | 0.66 | 4.89 | 103 | 157 | 420 | 136 | 41 |
| 36 | P198 (4)88- 93 | PC | 0.63 | 4.97 | 101 | 165 | 414 | 159 | 89 |
| 37 | P198 (5)38- 43 | PC | 0.74 | 5.01 | 114 | 173 | 482 | 149 | 86 |
| 38 | P198 (5)88- 93 | PC | 0.70 | 5.12 | 117 | 150 | 494 | 212 | 55 |
| 39 | P198 (6)38- 43 | PC | 0.71 | 5.02 | 115 | 165 | 514 | 143 | 41 |
| 40 | P198 (6)88- 93 | PC | 0.79 | 5.23 | 125 | 193 | 585 | 166 | 52 |
| 41 | P198 (7)38- 43 | PC | 0.82 | 5.04 | 133 | 238 | 576 | 242 | 55 |
| 42 | P198 (7)88- 93 | PC | 0.83 | 4.98 | 137 | 238 | 630 | 225 | 44 |
| 43 | P198 (8)38- 43 | PC | 0.83 | 4.89 | 126 | 222 | 595 | 161 | 37 |
| 44 | P198 (8)88- 93 | PC | 0.88 | 4.93 | 138 | 281 | 695 | 157 | 49 |

Table XIII-1 (continued)

| Analysis No. | Sample No. | | Sediment Type | Mn % | Fe % | Co ppm | Ni ppm | Cu ppm | Zn ppm | Pb ppm |
|---|---|---|---|---|---|---|---|---|---|---|
| 45 | P204 | (2) 3- 8 | SRC | 0.80 | 5.24 | 130 | 184 | 428 | 139 | 51 |
| 46 | P204 | (2)40- 45 | PC | 0.90 | 5.32 | 133 | 241 | 460 | 171 | 57 |
| 47 | P204 | (2)90- 95 | PC | 0.95 | 5.50 | 141 | 264 | 498 | 177 | 54 |
| 48 | P204 | (3)40- 45 | PC | 1.04 | 5.33 | 153 | 310 | 554 | 187 | 44 |
| 49 | P204 | (3)90- 95 | PC | 1.15 | 5.12 | 152 | 383 | 607 | 174 | 52 |
| 50 | P204 | (4)40- 45 | PC | 0.45 | 5.16 | 128 | 126 | 604 | 178 | 59 |
| 51 | P204 | (4)90- 95 | PC | 1.36 | 5.42 | 176 | 371 | 674 | 249 | 63 |
| 52 | P204 | (5)40- 45 | ZC | 1.14 | 4.50 | 183 | 390 | 597 | 385 | 47 |
| 53 | P204 | (5)90- 95 | ZC | 1.01 | 4.61 | 165 | 353 | 816 | 464 | 56 |
| 54 | P204 | (6)40- 45 | ZC | 1.17 | 5.28 | 165 | 352 | 468 | 606 | 43 |
| 55 | P204 | (6)90- 95 | ZC | 1.13 | 4.50 | 153 | 345 | 613 | 266 | 44 |
| 56 | P204 | (7)40- 45 | ZC | 1.19 | 4.35 | 141 | 385 | 749 | 260 | 39 |
| 57 | P204 | (8)40- 45 | SO | 0.06 | 0.29 | 6 | 16 | 60 | 22 | 2 |
| 58 | P204 | (8)90- 95 | SO | 0.05 | 0.21 | 3 | 13 | 44 | 40 | 8 |
| 59 | P206 | (2)65- 70 | SRC | 0.61 | 4.78 | 119 | 125 | 397 | 376 | 48 |
| 60 | P206 | (3)15- 20 | PC | 0.74 | 5.16 | 130 | 145 | 414 | 226 | 42 |
| 61 | P206 | (3)65- 70 | PC | 0.78 | 5.29 | 138 | 157 | 442 | 236 | 56 |
| 62 | P206 | (4)15- 20 | PC | 0.70 | 5.02 | 120 | 153 | 423 | 127 | 54 |
| 63 | P206 | (4)65- 70 | PC | 0.69 | 5.00 | 115 | 148 | 408 | 332 | 78 |
| 64 | P206 | (5)15- 20 | PC | 0.88 | 5.13 | 131 | 209 | 468 | 136 | 44 |
| 65 | P206 | (5)65- 70 | PC | 0.70 | 5.28 | 132 | 169 | 507 | 215 | 50 |
| 66 | P206 | (6)15- 20 | PC | 0.82 | 5.41 | 134 | 201 | 504 | 199 | 44 |
| 67 | P206 | (6)65- 70 | PC | 0.90 | 5.55 | 148 | 211 | 538 | 238 | 51 |
| 68 | P206 | (7)15- 20 | PC | 0.99 | 5.34 | 164 | 299 | 563 | 221 | 50 |
| 69 | P206 | (7)65- 70 | PC | 0.88 | 5.15 | 139 | 204 | 518 | 145 | 49 |
| 70 | P206 | (8)15- 20 | PC | 0.95 | 5.01 | 154 | 254 | 633 | 190 | 54 |
| 71 | P206 | (8)65- 70 | PC | 0.92 | 5.02 | 153 | 224 | 546 | 261 | 46 |
| 72 | P207 | (1)95-100 | SRC | 0.37 | 4.44 | 99 | 78 | 305 | 382 | 54 |
| 73 | P207 | (2)45- 50 | SRC | 0.74 | 5.26 | 126 | 178 | 411 | 129 | 36 |
| 74 | P207 | (2)95-100 | PC | 0.88 | 5.69 | 149 | 203 | 473 | 175 | 40 |
| 75 | P207 | (3)45- 50 | PC | 1.00 | 5.55 | 142 | 311 | 515 | 174 | 52 |
| 76 | P207 | (3)95-100 | PC | 0.87 | 5.61 | 152 | 228 | 516 | 178 | 50 |
| 77 | P207 | (4)45- 50 | PC | 0.90 | 5.95 | 171 | 240 | 550 | 234 | 48 |
| 78 | P207 | (4)95-100 | PC | 0.50 | 5.53 | 137 | 168 | 576 | 166 | 56 |
| 79 | P207 | (5)45- 50 | PC | 0.49 | 5.52 | 227 | 215 | 736 | 209 | 51 |
| 80 | P207 | (5)95-100 | ZC | 1.74 | 5.22 | 125 | 715 | 640 | 255 | 47 |
| 81 | P207 | (6)45- 50 | ZC | 1.12 | 4.65 | 142 | 513 | 526 | 228 | 39 |
| 82 | P207 | (6)95-100 | ZC | 1.01 | 4.53 | 124 | 442 | 524 | 205 | 37 |
| 83 | P207 | (7)45- 50 | ZC | 1.06 | 4.21 | 135 | 366 | 647 | 304 | 40 |
| 84 | P207 | (7)95-100 | ZC | 0.79 | 4.03 | 82 | 281 | 558 | 243 | 30 |
| 85 | P207 | (8)45- 50 | ZC | 0.29 | 1.54 | 27 | 83 | 233 | 90 | 30 |
| 86 | P207 | (8)95-100 | CO | 0.11 | 0.58 | 18 | 39 | 87 | 150 | 36 |
| 87 | P194 | cc | CH | 0.53 | 4.83 | 88 | 151 | 604 | 145 | 36 |
| 88 | B33 | | PC | 0.58 | 4.71 | 96 | 160 | 534 | 156 | 30 |

Table XIII–1 (continued)

| Analysis No. | Sample No. | Sediment Type | Mn % | Fe % | Co ppm | Ni ppm | Cu ppm | Zn ppm | Pb ppm |
|---|---|---|---|---|---|---|---|---|---|
| 89 | B34 | SRC | 0.51 | 4.65 | 86 | 125 | 489 | 139 | 28 |
| 90 | B35 | PC | 0.53 | 4.60 | 102 | 114 | 396 | 129 | 36 |
| 91 | B36 | SRC | 0.52 | 4.69 | 80 | 118 | 395 | 136 | 35 |
| 92 | B37 | SC | 0.38 | 4.37 | 72 | 82 | 427 | 121 | 26 |
| 93 | B38 | SRC | 0.58 | 4.72 | 91 | 150 | 484 | 158 | 42 |
| 94 | B39 | SRC | 0.50 | 4.49 | 88 | 115 | 388 | 123 | 44 |
| 95 | B40 | SRC | 0.68 | 4.69 | 105 | 197 | 513 | 140 | 40 |
| 96 | B41 | SRC | 0.55 | 4.32 | 91 | 119 | 394 | 123 | 34 |
| 97 | B42 | SRC | 0.46 | 4.15 | 84 | 185 | 365 | 144 | 33 |
| 98 | B43 | SRC | 0.79 | 4.58 | 110 | 226 | 489 | 151 | 37 |
| 99 | B44 | SRC | 0.54 | 4.39 | 88 | 115 | 407 | 134 | 30 |
| 100 | B45 | SRC | 0.68 | 4.44 | 106 | 190 | 439 | 145 | 27 |
| 101 | B47 | SRC | 0.53 | 4.37 | 86 | 121 | 390 | 138 | 35 |
| 102 | B48 | SRC | 0.60 | 4.38 | 100 | 159 | 414 | 127 | 37 |
| 103 | B49 | SRC | 0.78 | 4.22 | 107 | 234 | 476 | 148 | 33 |
| 104 | B50 | SRC | 0.86 | 4.38 | 112 | 260 | 519 | 142 | 39 |
| 105 | B51 | SRC | 0.90 | 4.28 | 107 | 268 | 544 | 141 | 34 |
| 106 | B52 | SRC | 0.58 | 4.34 | 92 | 139 | 418 | 125 | 34 |
| 107 | B53 | SRC | 0.50 | 4.14 | 86 | 112 | 365 | 158 | 29 |
| 108 | B54 | SRC | 0.76 | 4.51 | 113 | 217 | 485 | 196 | 37 |
| 109 | B55 | SRC | 0.74 | 4.26 | 106 | 221 | 465 | 139 | 38 |

Table XIII–2 Averages, minimums, maximums, and standard deviations. Unit of concentrations is % for Mn and Fe, or ppm for the other elements

(a) All samples (n=109)

| | Mn | Fe | Co | Ni | Cu | Zn | Pb |
|---|---|---|---|---|---|---|---|
| AVE. | 0.80 | 4.59 | 118 | 216 | 509 | 209 | 44 |
| MIN. | 0.05 | 0.21 | 3 | 13 | 44 | 22 | 2 |
| MAX. | 1.74 | 5.95 | 227 | 715 | 903 | 643 | 89 |
| S.D. | 0.27 | 0.95 | 34 | 102 | 145 | 102 | 12 |

(b) Siliceous fossil rich clay facies (n=26)

| | Mn | Fe | Co | Ni | Cu | Zn | Pb |
|---|---|---|---|---|---|---|---|
| AVE. | 0.65 | 4.51 | 101 | 163 | 439 | 177 | 38 |
| MIN. | 0.37 | 3.83 | 80 | 105 | 365 | 125 | 27 |
| MAX. | 1.07 | 5.26 | 130 | 268 | 544 | 539 | 62 |
| S.D. | 0.16 | 0.31 | 13 | 53 | 65 | 97 | 8 |

(c) Pelegic clay facies (n=44)

| | Mn | Fe | Co | Ni | Cu | Zn | Pb |
|---|---|---|---|---|---|---|---|
| AVE. | 0.80 | 5.18 | 134 | 213 | 528 | 213 | 51 |
| MIN. | 0.45 | 4.60 | 96 | 145 | 408 | 136 | 37 |
| MAX. | 1.36 | 5.95 | 227 | 383 | 736 | 643 | 63 |
| S.D. | 0.17 | 0.28 | 24 | 67 | 95 | 97 | 11 |

(d) Zeolitic clay facies (n=33)

| | Mn | Fe | Co | Ni | Cu | Zn | Pb |
|---|---|---|---|---|---|---|---|
| AVE. | 1.02 | 4.26 | 124 | 285 | 575 | 248 | 43 |
| MIN. | 0.29 | 3.88 | 82 | 185 | 461 | 186 | 31 |
| MAX. | 1.74 | 5.28 | 186 | .715 | 816 | 606 | 56 |
| S.D. | 0.23 | 0.73 | 33 | 122 | 161 | 99 | 9 |

*Horizontal and vertical distribution of the elements*

Any systematic change cannot be recognized in horizontal distribution of the elements for the surface sediments which all belong to siliceous fossil rich clay. Vertical distribution of the elements in six sediment cores are shown in Fig. XIII–1. It is rather uniform in the cores obtained from the detailed survey area 1 (Figs. XIII–1 (a)～(c)) than those from the detailed survey area 2 (Figs. XIII–1(d)～(f)).

Manganese contents in the uppermost portion of each core are usually lower than those in the second depth. Increasing tendency of manganese to the deeper part is common in pelagic clay facies. In zeolitic clay facies, however, both decreasing and increasing tendencies are observed depending on the core. Abrupt decreasing of

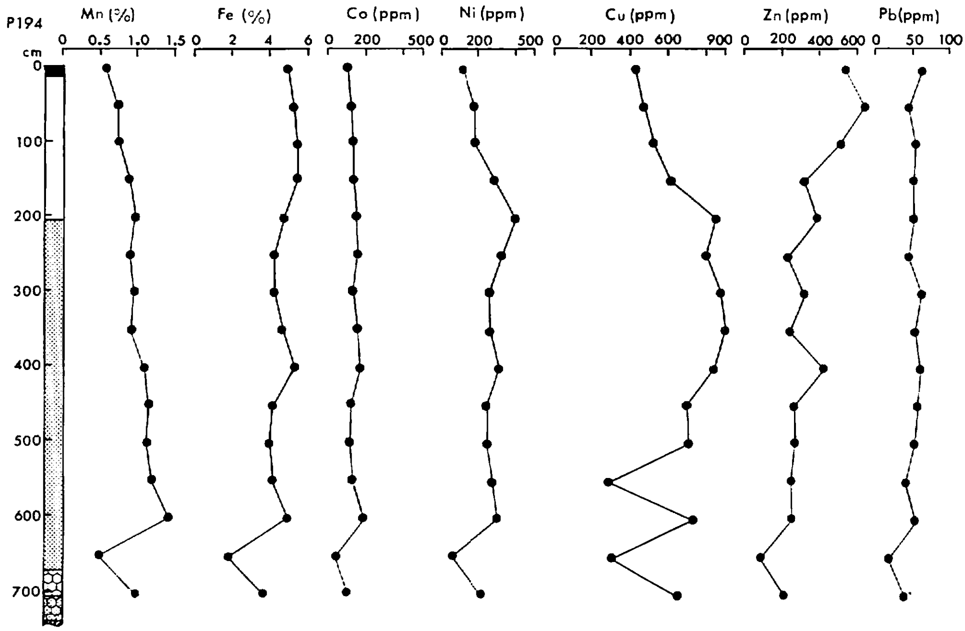


Fig. XIII-1 (a)

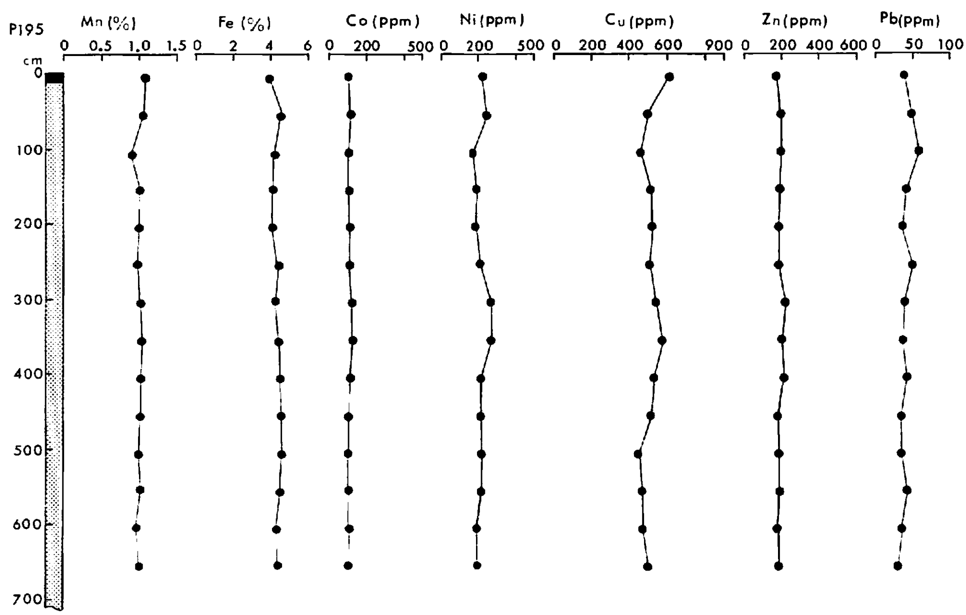


Fig. XIII-1 (b)

Fig. XIII-1 Vertical distribution of minor chemical composition in some selected cores. Sediment types (shown in the figure(e)) in the columns, are 1: siliceous fossil rich clay, 2: siliceous clay, 3: siliceous ooze, 4: pelagic clay, 5: zeolitic clay, 6: calcareous ooze and 7: chert.

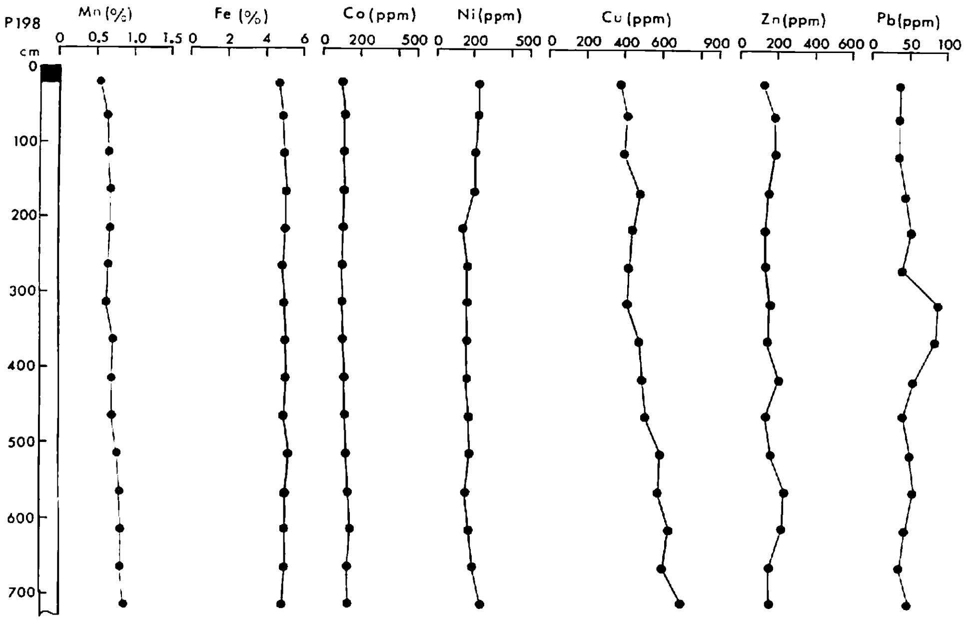


Fig. XIII-1 (c)

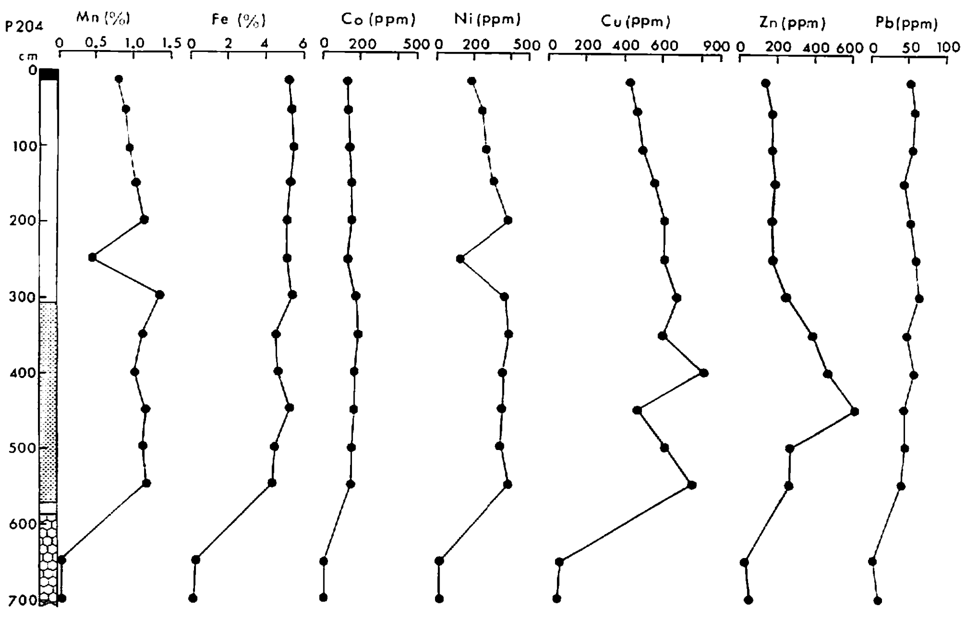


Fig. XIII-1 (d)

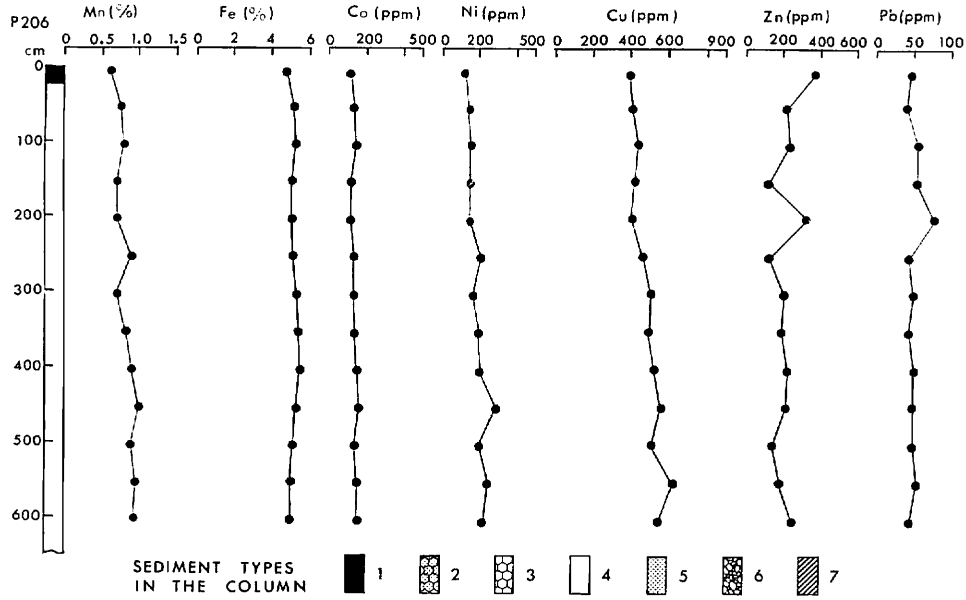


Fig. XIII-1 (e)

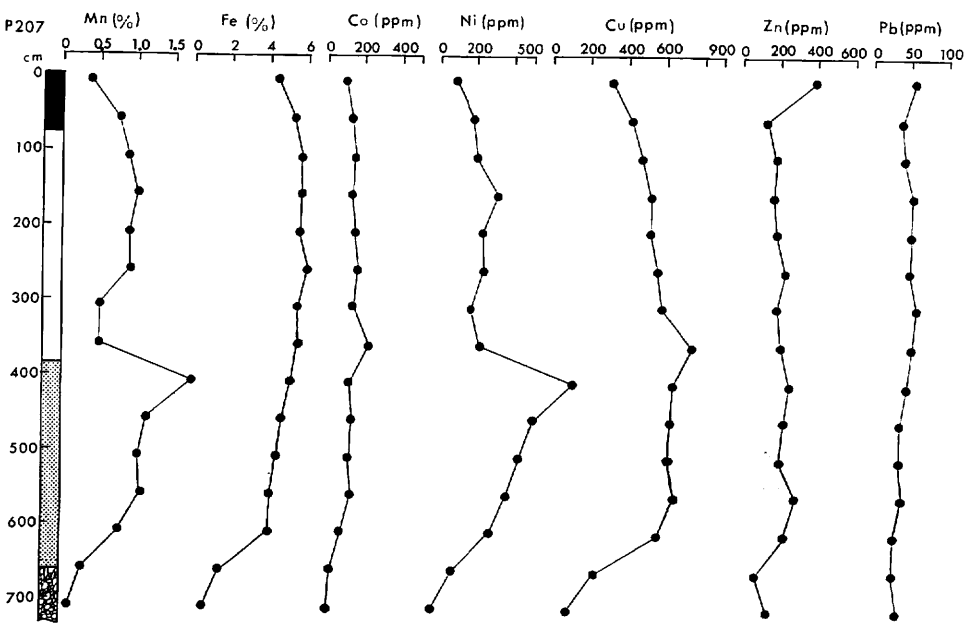


Fig. XIII-1 (f)

manganese content is observed in the cores (1) P194, lowermost part of zeolitic clay, around the portion of 650 cm deep, (2) P204, lower part of pelagic clay, around 250 cm deep, (3) P204, near the bottom of the core (siliceous ooze), around 650 cm and 700 cm deep, (4) P207, bottom part of pelagic clay, around 300 cm and 350 cm deep, (5) P207, bottom part of the core (calcareous ooze), around 650 and 700 cm deep.

Among these portions, (2) and (4) are obviously decolorized (NISHIMURA, in this cruise report) suggesting a reducing process in sedimentary or diagenetic environment of those. Nickel has the commonest behavior with that of manganese in those cases, whereas copper behaves dependently or even on the contraries though it is well known that there is an intimate correlation between nickel and coppr in the Pacific manganese nodules.

On the other hand, the portions (3) and (5) shows siliceous ooze facies and calcareous ooze facies respectively (NISHIMURA, this cruise report). Outstandingly low contents of those elements in siliceous or calareous ooze are reported in KATO *et al.* (1979) and MITA *et al.* (1982). In the cases in this cruise, almost all elements

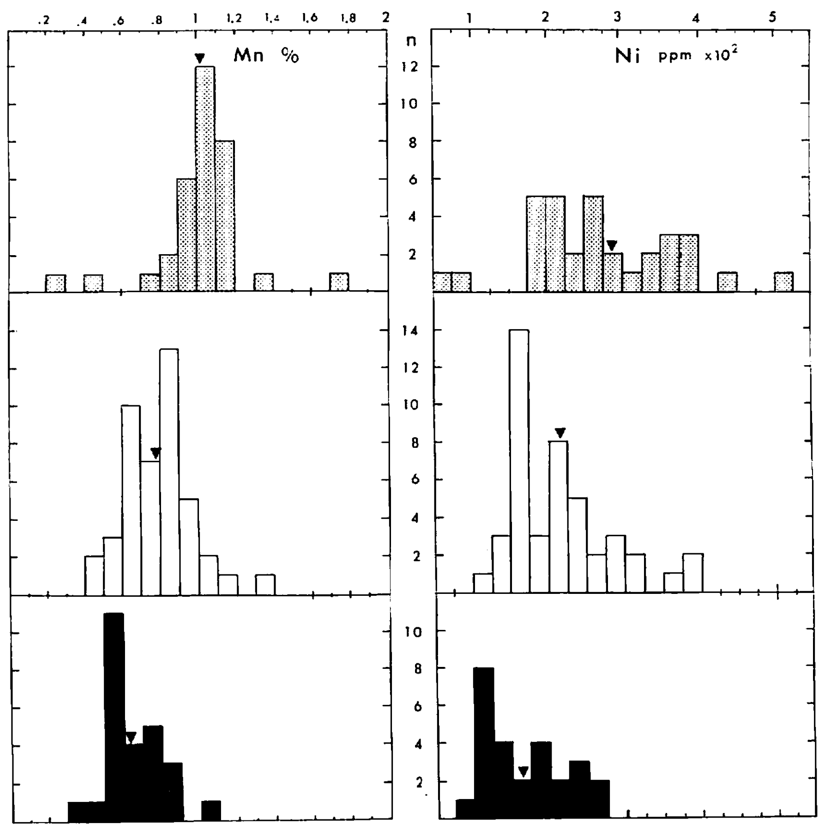


Fig. XIII-2 (a)

Fig. XIII-2 Histograms of the concentration of minor chemical composition for all samples and each major sediment facies.

analyzed have same tendencies, suggesting very low concentrations of them in siliceous or calcareous organic remains.

There is one portion showing abrupt increasing of manganese in P207 (uppermost part of zeolitic clay, around 400 cm deep), being concordant with that of nickel both accompanied by upward increasing tendency of these two elements in zeolitic clay layer. According to NISHIMURA (this cruise report), a manganese crust occurs near the top of this zeolitic clay layer. Hence the abrupt increasing of manganese mentioned above is though to be of diagenetic origin.

Somewhat irregular behavior of copper is observed, in P194 (around 550 cm), P195 (around the top), P204 (around 400 cm and 450 cm) or P207 (around 350 cm). Inconsistency of that compared with the other elements supports the hypothesis by Arrhenius (1963) that the source of the copper in the equatorial high productivity zone is most likely planctonic organisms.

*Sediment facies and concentrations of the elements*

Fig. XIII–2 shows histograms of the elements for each major sediment facies, i.e. siliceous fossil rich clay (bottom), pelegic clay (middle) and zeolitic clay (top). The elements in the figure (a) or (b) have a common tendency, namely average concentration of those is highest in zeolitic clay facies and is lowest in siliceous fossil

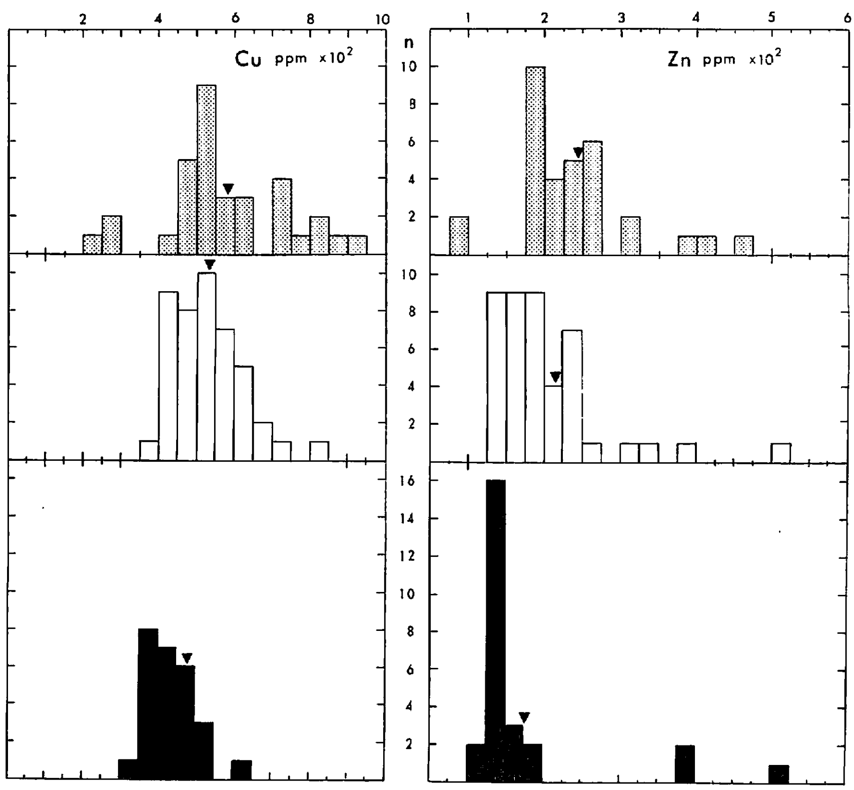


Fig. XIII–2 (b)

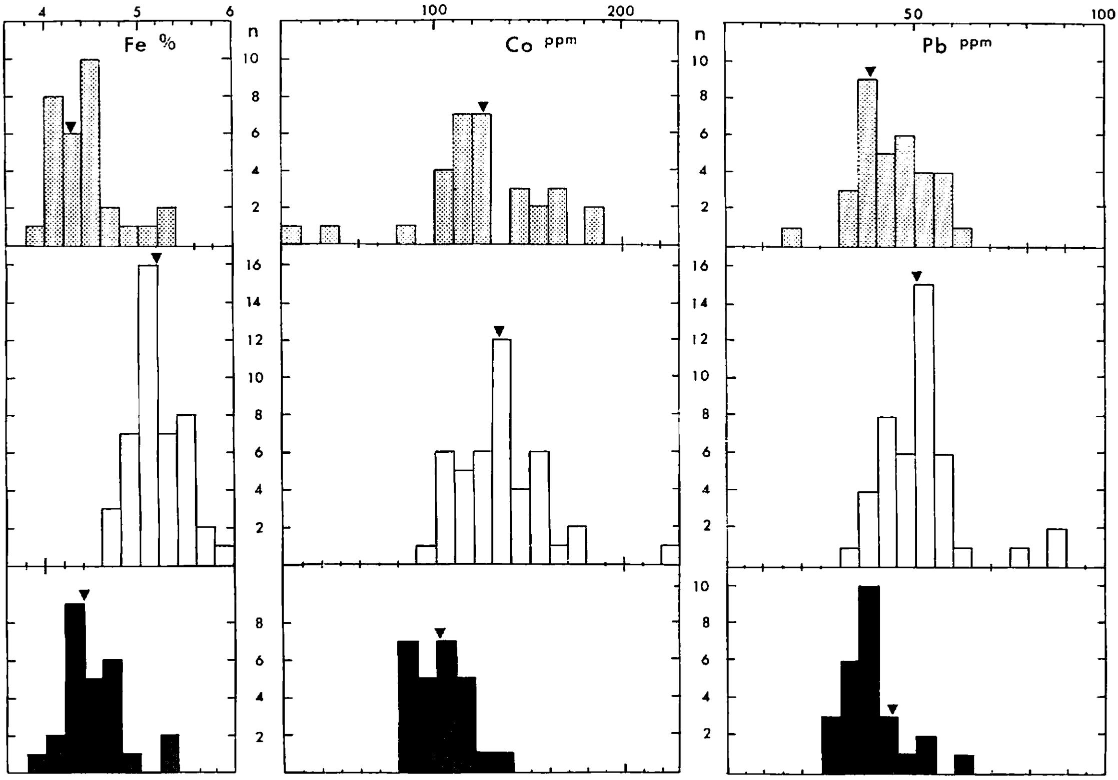

Fig. XIII-2 (c)

rich clay facies. On the other hand, Fe, Co, and Pb, in the figure (c), of which the highest averages appear for pelagic clay facies, and the lowest averages appear for zeolitic clay facies except Co.

Absolutely or relatively low averages of the elements, in siliceous fossil rich clay facies also suggest rather insignificant contribution of the siliceous fossils to concentrate those elements. MARCHING (1979) reported, in this connection, "radiolarian fraction" (coarser than 63 $\mu$m, nonmagnetic part) contains Fe, Mn, Cu, Ni and Co of which concentrations are far less than those in the fraction finer than 63 $\mu$m. On the other hand, higher concentrations of Mn, Ni, Cu and Zn in zeolitic clay facies than in pelagic clay facies may owe to a selective condensation of these elements during the genesis of manganese micronodules or selective adsorbance of them on zeolite minerals. Further study is necessary to solve this problem.

Lower concentrations of Fe, Co and Pb in zeolitic clay facies than in siliceous fossil rich clay facies and/or pelagic clay facies may owe largely to reduction of them in zeolite minerals. According to STONECIPHER (1978), phillipsites in north Pacific deep-sea sediments contain FeO (total iron as inclusion impurities, namely not included in cell contents) up to 0.98%, and clinoptilolites also in north Pacific deep-sea sediments does FeO up to 0.80%. Besides, in the relation to genesis of phillipsite, HONNOREZ (1978) reported an enrichment of Fe in an altered residual glass at the initial stage of palagonitization. Among the other two elements, especially Pb probably has similar behavior with Fe in that stage. KASTNER and STONECIPHER (1978) point out that the most common precursor for phillipsite seems to be palagonite, and that possible precursors for clinoptilolite include rhyolitic to andesitic glass, basaltic glass + silica (mainly biogenic), smectite + phillipsite + biogenic silica, and perhaps smectite + biogenic silica and biogenic silica + Al and K. Hence, the behavior of these elements during the genesis of clinoptilolite, which is major zeolite mineral in the zeolitic clay facies according to NISHIMURA (this cruise report), should not be simple unless exact precursor is specified.

*Correlation among the elements*

Coefficients of correlation among the elements in all samples and in the three sediment facies are shown in Table XIII-3. Estimation of the correlation among the elements, being carried out at 5% of level of significance, is as follows. For all samples (n = 109), any correlation cannot be observed if the coefficient (r) is less than 0.20. Critical value of the coefficient is 0.37 for siliceous fossil rich clay facies (n = 26), 0.29 for pelagic clay facies (n = 44) or 0.33 for zeolitic clay facies (n = 33) as well.

Outstandingly high coefficients (>0.75) are observed between Mn and Ni, and Fe and Co for all samples. Besides all the coefficients for all samples are more than the critical value, namely 0.20. In the case of siliceous fossil rich clay facies, There are strong correlation among Mn, Ni, and Cu. However coefficients between Cu and Mn or Ni decrease down to less than 0.7.

It is characteristic that the coefficients between Zn and the others less than the critical value, namely 0.29 as well as those between Pb and the others for pelagic clay facies.

There are strong correlations between Mn and Fe, Mn and Ni, and Fe and Co for the zeolitic clay facies. Among those the coefficients between Mn and Fe, and Fe and Co are, however, less than the critical value (0.37) for siliceous fossil rich clay facies. Besides, higher coefficients are observed among the elements for zeolitic

Table XIII-3 Coefficients of correlations among the elements.

(a) All samples (n=109)

| | | | | | | |
|---|---|---|---|---|---|---|
| Mn | | | | | | |
| 0.44 | Fe | | | | | |
| 0.67 | 0.76 | Co | | | | |
| 0.86 | 0.36 | 0.64 | Ni | | | |
| 0.63 | 0.50 | 0.73 | 0.65 | Cu | | |
| 0.35 | 0.30 | 0.46 | 0.36 | 0.38 | Zn | |
| 0.34 | 0.57 | 0.56 | 0.26 | 0.43 | 0.41 | Pb |

(b) Siliceous fossil rich clay facies (n=26)

| | | | | | | |
|---|---|---|---|---|---|---|
| Mn | | | | | | |
| 0.12 | Fe | | | | | |
| 0.69 | 0.42 | Co | | | | |
| 0.91 | 0.13 | 0.61 | Ni | | | |
| 0.84 | 0.20 | 0.37 | 0.81 | Cu | | |
| 0.21 | 0.22 | 0.20 | 0.29 | 0.20 | Zn | |
| 0.06 | 0.44 | 0.37 | 0.16 | 0.15 | 0.77 | Pb |

(c) Pelagic clay facies (n=44)

| | | | | | | |
|---|---|---|---|---|---|---|
| Mn | | | | | | |
| 0.30 | Fe | | | | | |
| 0.45 | 0.59 | Co | | | | |
| 0.84 | 0.21 | 0.58 | Ni | | | |
| 0.35 | 0.08 | 0.64 | 0.69 | Cu | | |
| 0.08 | 0.09 | 0.11 | 0.15 | 0.16 | Zn | |
| 0.04 | 0.10 | 0.02 | 0.03 | 0.01 | 0.07 | Pb |

(d) Zeolitic clay facies (n=33)

| | | | | | | |
|---|---|---|---|---|---|---|
| Mn | | | | | | |
| 0.81 | Fe | | | | | |
| 0.66 | 0.79 | Co | | | | |
| 0.76 | 0.63 | 0.60 | Ni | | | |
| 0.34 | 0.49 | 0.66 | 0.41 | Cu | | |
| 0.40 | 0.57 | 0.71 | 0.43 | 0.46 | Zn | |
| 0.42 | 0.52 | 0.62 | 0.27 | 0.64 | 0.49 | Pb |

clay facies compared to other two sedimentary facies. It may suggest these elements have a relatively common behavior during the genesis of zeolite minerals.

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