

# Supplementary Materials: Marine Phosphorites as Potential Resources for Heavy Rare Earth Elements and Yttrium

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**Table S1.** Chemical composition of marine phosphorites.

| Cruise ID                     | --              | AVON02       | AVON02       | AVON02       | F10-89-CP   | F7-86-HW     | F7-86-HW     | TN037        | TN037 <sup>1</sup> | TUNES6      | TUNES6      | V2-91-CP <sup>1</sup> | V2-91-CP <sup>1</sup> |
|-------------------------------|-----------------|--------------|--------------|--------------|-------------|--------------|--------------|--------------|--------------------|-------------|-------------|-----------------------|-----------------------|
| Water                         | --              | 1588         | 1588         | 2966         | 1900        | 2480         | 1935         | 3474         | 3016               | 3395        | 3395        | 3100                  | 4425                  |
| Depth (m)                     | --              |              |              |              |             |              |              |              |                    |             |             |                       |                       |
| Latitude                      | --              | 0°11.28' N   | 0°11.28' N   | 7°40.86' N   | 11°51.09' N | 16°26.8' N   | 16°33.33' N  | 36°8.070' N  | 32°12.93' N        | 16°25.3' N  | 16°25.3' N  | 16°35.35' N           | 17°14.25' N           |
| Longitude                     | --              | 173°36.48' E | 173°36.48' E | 173°16.92' E | 161°28.5' E | 169°32.95' W | 168°16.61' W | 158°22.45' E | 158°36.21' E       | 154°21.1' E | 154°21.1' E | 168°24.36' W          | 168°14.95' W          |
| Location                      | --              | C. Pacific   | C. Pacific   | C. Pacific   | C. Pacific  | C. Pacific   | C. Pacific   | C. Pacific   | C. Pacific         | C. Pacific  | C. Pacific  | C. Pacific            | C. Pacific            |
| Sample No.                    | Detection Limit | 11 MASSIVE   | 11 POROUS    | 55-13        | D10-17      | CD19-1A      | CD30-8       | D10-M-1      | D12-2              | D32-6       | D32-9       | D4-12                 | D7-8                  |
| Fe (wt %)                     | 0.01            | 0.06         | 0.43         | 0.15         | 0.41        | 0.78         | 0.63         | 0.41         | 0.35               | 2.89        | 0.30        | 1.06                  | 0.45                  |
| Si                            | 0.01            | 0.03         | 0.17         | 0.90         | 0.81        | 2.36         | 2.64         | 4.15         | 1.36               | 7.15        | 0.71        | 3.80                  | 3.89                  |
| Al                            | 0.01            | 0.02         | 0.08         | 0.33         | 0.30        | 0.83         | 1.07         | 1.42         | 0.44               | 2.12        | 0.24        | 1.17                  | 1.31                  |
| Si/Al                         | 0.01            | 1.55         | 1.99         | 2.69         | 2.70        | 2.84         | 2.47         | 2.93         | 3.05               | 3.37        | 2.90        | 3.25                  | 2.96                  |
| Mg                            | 0.01            | 0.19         | 0.18         | 0.11         | 0.21        | 0.30         | 0.27         | 0.29         | 0.17               | 0.62        | 0.16        | 0.39                  | 0.38                  |
| Ca                            | 0.01            | 37.8         | 37.2         | 37.3         | 36.6        | 34.4         | 34.4         | 32.0         | 36.7               | 26.2        | 36.3        | 33.2                  | 33.6                  |
| Na                            | 0.01            | 0.69         | 0.83         | 0.97         | 0.84        | 0.82         | 0.88         | 0.91         | 0.66               | 1.09        | 0.56        | 0.68                  | 0.64                  |
| K                             | 0.01            | 0.02         | 0.03         | 0.19         | 0.12        | 0.36         | 0.26         | 0.74         | 0.29               | 0.86        | 0.09        | 0.68                  | 0.71                  |
| Ti                            | 0.01            | <0.01        | 0.02         | 0.02         | 0.07        | 0.05         | 0.10         | 0.04         | 0.02               | 0.28        | 0.03        | 0.16                  | 0.05                  |
| P                             | 0.01            | 10.8         | 14.0         | 14.0         | 13.6        | 12.9         | 13.0         | 12.3         | 14.0               | 9.95        | 12.3        | 12.7                  | 13.0                  |
| Ca/P                          | 0.01            | 3.51         | 2.67         | 2.66         | 2.70        | 2.66         | 2.66         | 2.61         | 2.63               | 2.64        | 2.96        | 2.61                  | 2.58                  |
| P <sub>2</sub> O <sub>5</sub> | 0.01            | 24.7         | 32.0         | 32.2         | 31.1        | 29.6         | 29.7         | 28.1         | 32.0               | 22.8        | 28.1        | 29.1                  | 29.8                  |
| S                             | 0.01            | 0.78         | 0.80         | 0.76         | 0.75        | 0.74         | 0.74         | 0.60         | 0.65               | 0.57        | 0.67        | 0.61                  | 0.54                  |
| SO <sub>3</sub>               | 0.01            | 1.95         | 2.00         | 1.90         | 1.87        | 1.85         | 1.85         | 1.50         | 1.62               | 1.42        | 1.67        | 1.52                  | 1.35                  |
| CO <sub>2</sub>               | 0.01            | --           | 6.85         | 5.55         | 6.96        | 5.13         | 4.80         | 3.89         | 5.33               | --          | --          | 3.75                  | 3.79                  |
| LOI <sup>2</sup>              | -10             | 17.5         | 9.45         | 8.07         | 9.71        | 8.09         | 7.59         | 7.60         | 7.02               | 10.2        | 10.2        | 7.52                  | 6.67                  |
| H <sub>2</sub> O <sup>+</sup> | 0.10            | --           | 2.60         | 1.90         | 2.80        | 2.40         | 2.10         | 1.90         | 2.10               | --          | --          | 2.00                  | 2.20                  |
| Ag (ppm)                      | 0.02            | <0.02        | 0.15         | <0.02        | <0.02       | 0.03         | 0.03         | <0.02        | <0.02              | <0.02       | <0.02       | <0.02                 | <0.02                 |
| As                            | 1               | 5.0          | 9.0          | 3.0          | 5.0         | 7.0          | 5.0          | 5.0          | 4.0                | 7.0         | 4.0         | 5.0                   | 3.0                   |
| Ba                            | 1               | 84           | 34           | 111          | 20          | 1830         | 67           | 1190         | 35                 | 408         | 1900        | 78                    | 33                    |
| Be                            | 0.1             | 0.30         | 0.30         | 0.40         | 0.40        | 0.70         | 0.50         | 0.40         | 0.50               | 0.40        | 0.40        | 0.40                  | 0.50                  |
| Bi                            | 0.04            | 0.08         | 0.22         | 0.04         | 0.08        | 0.23         | 0.14         | 0.16         | 0.07               | 0.46        | 0.25        | 0.05                  | <0.04                 |
| Cd                            | 0.02            | 0.70         | 0.38         | 0.16         | 0.32        | 0.17         | 0.44         | 0.46         | 0.45               | 0.37        | 0.26        | 0.14                  | 0.22                  |
| Cl                            | 50              | 650          | 630          | 3410         | 1940        | 1110         | 800          | 310          | 670                | 2680        | 710         | 890                   | 690                   |
| Co                            | 0.1             | 8.8          | 68           | 5.9          | 7.1         | 33           | 27           | 20           | 1.8                | 54          | 17          | 3.1                   | 1.7                   |
| Cr                            | 1               | 48           | 9.0          | 7.0          | 16          | 14           | 13           | 13           | 30                 | 51          | 28          | 14                    | 14                    |
| Cs                            | 0.1             | <0.1         | <0.1         | <0.1         | 0.20        | 1.3          | 0.30         | 0.60         | 0.40               | 1.1         | 0.20        | 0.60                  | 0.70                  |
| Cu                            | 0.5             | 16           | 50           | 29           | 67          | 94           | 65           | 205          | 35                 | 156         | 111         | 64                    | 37                    |
| F                             | 25              | 20,300       | 30,000       | 26,800       | 30,300      | 24,900       | 28,600       | 12,300       | 30,000             | 20,500      | 28,300      | 28,200                | 29,000                |

Table S1. Cont.

| Sample No.                    | Detection Limit | 11 MASSIVE | 11 POROUS | 55-13 | D10-17 | CD19-1A | CD30-8 | D10-M-1 | D12-2 | D32-6 | D32-9 | D4-12 | D7-8  |
|-------------------------------|-----------------|------------|-----------|-------|--------|---------|--------|---------|-------|-------|-------|-------|-------|
| Ga                            | 0.1             | 0.70       | 0.90      | 1.2   | 1.6    | 3.3     | 2.7    | 5.1     | 2.0   | 4.8   | 2.0   | 5.7   | 4.5   |
| Hf                            | 0.02            | 0.10       | 0.14      | 0.08  | 0.11   | 0.26    | 0.04   | 0.32    | 0.15  | 0.40  | 0.08  | 0.11  | 0.14  |
| In                            | 0.02            | <0.02      | <0.02     | <0.02 | <0.02  | 0.02    | <0.02  | 0.02    | <0.02 | 0.03  | <0.02 | <0.02 | <0.02 |
| Li                            | 1               | <1         | <1        | <1    | 2.0    | 6.0     | 6.0    | 11      | 2.0   | 20    | 1.0   | 5.0   | 6.0   |
| Mo                            | 0.05            | 2.2        | 4.7       | 0.88  | 1.2    | 3.4     | 1.9    | 6.7     | 3.4   | 7.3   | 4.5   | 0.75  | 0.77  |
| Mn                            | 0.01            | 465        | 2014      | 310   | 155    | 1549    | 1084   | 3873    | 46    | 3563  | 1317  | 92    | 56    |
| Nb                            | 0.1             | <1         | 2.0       | 1.0   | 4.0    | 3.0     | 8.0    | 2.0     | 3.0   | 17    | 2.0   | 7.0   | 3.0   |
| Ni                            | 0.5             | 33         | 139       | 43    | 35     | 152     | 78     | 366     | 33    | 308   | 150   | 28    | 21    |
| Pb                            | 0.5             | 5.2        | 13        | 1.9   | 3.0    | 7.7     | 15     | 7.4     | 5.0   | 15    | 7.4   | 1.5   | 1.1   |
| Rb                            | 0.2             | <0.2       | 0.50      | 3.1   | 2.7    | 13      | 6.2    | 12      | 7.5   | 18    | 2.8   | 15    | 15    |
| Sb                            | 0.05            | 1.6        | 1.6       | 1.1   | 1.9    | 1.2     | 0.82   | 1.5     | 0.82  | 2.9   | 0.49  | 1.4   | 0.80  |
| Sc                            | 0.5             | 2.8        | 8.0       | 2.6   | 3.5    | 8.3     | 2.5    | 14      | 4.1   | 7.6   | 3.4   | 5.6   | 7.3   |
| Se                            | 2               | 2.0        | 3.0       | <2    | 3.0    | 5.0     | <2     | 5.0     | 3.0   | 4.0   | <2    | <2    | 2.0   |
| Sn                            | 0.3             | <0.3       | 0.30      | <0.3  | <0.3   | 0.70    | 4.0    | 0.40    | <0.3  | 1.4   | 0.90  | 0.40  | 0.30  |
| Sr                            | 0.5             | 1470       | 1490      | 1170  | 1440   | 1330    | 1160   | 1180    | 1120  | 724   | 1920  | 914   | 757   |
| Ta                            | 0.05            | <0.05      | <0.05     | <0.05 | <0.05  | 0.07    | <0.05  | 0.08    | <0.05 | 0.09  | <0.05 | <0.05 | <0.05 |
| Te                            | 0.05            | 0.32       | 0.97      | 0.18  | 0.17   | 0.40    | 0.19   | 0.30    | 0.23  | 0.76  | 0.33  | 0.19  | 0.07  |
| Th                            | 0.2             | <0.2       | <0.2      | <0.2  | 0.20   | 0.90    | 0.60   | 1.0     | 0.50  | 2.3   | 0.40  | 1.0   | 0.80  |
| Tl                            | 0.02            | 0.04       | 0.95      | 0.31  | 0.11   | 0.76    | 1.1    | 2.2     | 0.08  | 1.4   | 0.40  | 0.14  | 0.19  |
| U                             | 0.05            | 8.7        | 11        | 5.3   | 8.4    | 7.4     | 6.4    | 5.1     | 7.6   | 4.7   | 5.3   | 6.1   | 4.7   |
| V                             | 5               | 35         | 35        | 22    | 31     | 44      | 28     | 23      | 34    | 59    | 28    | 34    | 25    |
| W                             | 0.1             | 0.70       | 1.0       | 0.20  | 0.20   | 1.0     | 0.30   | 1.1     | 0.20  | 1.1   | 0.50  | 0.10  | 0.20  |
| Zn                            | 1               | 49         | 48        | 32    | 49     | 58      | 100    | 56      | 38    | 76    | 41    | 42    | 26    |
| Zr                            | 0.5             | 9.5        | 76        | 51    | 82     | 158     | 211    | 88      | 84    | 114   | 72    | 77    | 65    |
| La <sup>3</sup>               | 0.1             | 69.6       | 89.7      | 51.2  | 61.5   | 176     | 16.6   | 214     | 111   | 164   | 67.7  | 46.0  | 157   |
| Ce                            | 0.1             | 11.6       | 12.6      | 3.10  | 10.1   | 14.8    | 25.1   | 21.1    | 8.20  | 30.2  | 13.6  | 18.7  | 11.3  |
| Pr                            | 0.05            | 8.39       | 8.98      | 7.02  | 7.96   | 24.7    | 2.85   | 36.8    | 14.3  | 28.4  | 9.43  | 8.44  | 15.2  |
| Nd                            | 0.1             | 34.6       | 39.0      | 31.0  | 35.3   | 109     | 11.9   | 153     | 59.6  | 122   | 38.5  | 33.6  | 59.5  |
| Sm                            | 0.1             | 6.50       | 7.10      | 5.80  | 6.60   | 20.7    | 2.40   | 31.1    | 10.8  | 23.8  | 7.00  | 6.30  | 9.30  |
| Eu                            | 0.05            | 1.99       | 2.33      | 1.78  | 1.96   | 6.11    | 0.73   | 8.31    | 2.98  | 6.90  | 1.63  | 1.77  | 2.61  |
| Gd                            | 0.05            | 11.9       | 14.5      | 10.1  | 11.8   | 35.4    | 3.47   | 42.5    | 17.4  | 37.2  | 9.58  | 8.72  | 16.2  |
| Tb                            | 0.05            | 1.65       | 2.07      | 1.32  | 1.67   | 4.65    | 0.46   | 5.67    | 2.34  | 4.77  | 1.32  | 1.22  | 2.13  |
| Dy                            | 0.05            | 11.5       | 16.8      | 10.0  | 12.8   | 33.9    | 3.03   | 38.7    | 17.1  | 31.5  | 8.94  | 8.45  | 16.2  |
| Y                             | 0.5             | 155        | 365       | 134   | 187    | 437     | 38.9   | 400     | 223   | 307   | 99.9  | 74.6  | 261   |
| Ho                            | 0.05            | 2.85       | 4.80      | 2.48  | 3.29   | 8.27    | 0.71   | 8.69    | 4.20  | 6.68  | 2.09  | 1.85  | 4.34  |
| Er                            | 0.05            | 9.09       | 17.3      | 7.61  | 10.8   | 25.9    | 2.29   | 26.9    | 13.8  | 19.8  | 6.63  | 5.76  | 14.4  |
| Tm                            | 0.05            | 1.26       | 2.48      | 1.02  | 1.52   | 3.58    | 0.34   | 3.88    | 2.02  | 2.56  | 0.96  | 0.82  | 2.10  |
| Yb                            | 0.1             | 8.30       | 17.1      | 6.80  | 10.4   | 24.7    | 2.40   | 27.2    | 14.1  | 15.9  | 6.90  | 5.70  | 15.0  |
| Lu                            | 0.05            | 1.27       | 2.72      | 1.03  | 1.63   | 3.85    | 0.35   | 4.19    | 2.21  | 2.34  | 1.04  | 0.86  | 2.30  |
| EREY <sup>4</sup>             | --              | 336        | 602       | 274   | 364    | 929     | 112    | 1022    | 503   | 803   | 275   | 223   | 589   |
| %HREY <sup>5</sup>            | --              | 61         | 74        | 64    | 67     | 63      | 47     | 55      | 59    | 54    | 51    | 49    | 57    |
| Ce <sub>en</sub> <sup>6</sup> | --              | 0.20       | 0.21      | 0.06  | 0.19   | 0.09    | 1.29   | 0.08    | 0.08  | 0.16  | 0.21  | 0.33  | 0.11  |
| Ce <sub>sn</sub> <sup>6</sup> | --              | 0.15       | 0.16      | 0.05  | 0.14   | 0.07    | 0.98   | 0.06    | 0.06  | 0.12  | 0.16  | 0.25  | 0.08  |

Table S1. Cont.

| Cruise ID                     | SO66 7       | SO66 7       | SO66 7       | SO66 7       | SO66 7       | SO66 7       | SO66 7       | SO66 7       | SO66 7       | L5-83-HW 7  | L5-83-HW 7  | F7-86-HW 7  | F2-88-HW 7  |
|-------------------------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|-------------|-------------|-------------|-------------|
| Water                         | 1408         | 1408         | 3033         | 2550         | 1406         | 2821         | 2000         | 1787         | 2600         | 2225        | 1400        | 2435        | 2695        |
| Depth (m)                     | 1408         | 1408         | 3033         | 2550         | 1406         | 2821         | 2000         | 1787         | 2600         | 2225        | 1400        | 2435        | 2695        |
| Latitude                      | 2°41.60' S   | 2°41.60' S   | 4°09.74' S   | 4°09.54' S   | 4°08.41' S   | 8°24.56' S   | 2°03.38' S   | 2°01.30' S   | 9°56.71' S   | 22°18.6' N  | 08°18.3' N  | 16°26.5' N  | 18°38.2' N  |
| Longitude                     | 175°07.22' W | 175°07.22' W | 174°53.79' W | 174°52.57' W | 174°50.75' W | 177°20.01' E | 176°13.55' E | 176°09.59' E | 179°55.86' E | 166°54.0' W | 164°21.6' W | 169°33.0' W | 155°58.2' W |
| Location                      | C. Pacific   | C. Pacific   | C. Pacific   | C. Pacific   | C. Pacific   | C. Pacific   | C. Pacific   | C. Pacific   | C. Pacific   | C. Pacific  | C. Pacific  | C. Pacific  | C. Pacific  |
| Sample No.                    | 26 DSR 1     | 26 DSR 2     | 28 DSR 6     | 29 DSR 5     | 50 DSR 3     | 61 DSR 1     | 69 DSO 2     | 80 DSK 6     | 85 DSK 1     | D5-A3-2     | D29-A1-1b   | CD14-2D     | D12-1A      |
| Fe (wt %)                     | 0.22         | 0.10         | 0.24         | 0.66         | 0.19         | 0.18         | 1.38         | 0.01         | 0.01         | 1.03        | 0.10        | 0.90        | 0.59        |
| Si                            | 0.41         | 0.34         | 1.22         | 2.01         | 0.42         | 0.47         | 3.82         | 0.36         | 0.32         | 5.28        | 0.50        | 2.29        | 2.41        |
| Al                            | 0.08         | 0.07         | 0.37         | 0.65         | 0.08         | 0.14         | 1.48         | 0.08         | 0.05         | 1.88        | 0.19        | 0.70        | 0.78        |
| Si/Al                         | 5.12         | 4.89         | 3.28         | 3.11         | 4.97         | 3.27         | 2.59         | 4.59         | 6.01         | 2.81        | 2.63        | 3.28        | 3.07        |
| Mg                            | 0.22         | 0.18         | 0.10         | 0.17         | 0.14         | 0.28         | 0.30         | 0.04         | 0.05         | 0.36        | 0.13        | 0.28        | 0.21        |
| Ca                            | 36.4         | 37.6         | 36.3         | 35.2         | 37.4         | 36.2         | 32.5         | 37.9         | 37.4         | 30.4        | 36.9        | 33.2        | 34.9        |
| Na                            | 0.81         | 0.76         | 0.65         | 0.68         | 0.73         | 0.78         | 0.65         | 0.68         | 0.73         | 0.51        | 0.75        | 0.85        | 0.55        |
| K                             | 0.03         | 0.03         | 0.04         | 0.08         | 0.03         | 0.03         | 0.13         | 0.02         | 0.02         | 0.69        | 0.03        | 0.28        | 0.32        |
| Ti                            | 0.03         | 0.01         | 0.02         | 0.04         | 0.01         | 0.04         | 0.22         | 0.006        | 0.004        | 0.12        | <0.02       | 0.07        | 0.08        |
| P                             | 13.8         | 14.5         | 13.9         | 13.3         | 14.2         | 13.8         | 12.4         | 14.6         | 14.2         | 11.8        | 14.0        | 12.6        | 13.4        |
| Ca/P                          | 2.63         | 2.59         | 2.61         | 2.64         | 2.63         | 2.63         | 2.63         | 2.59         | 2.63         | 2.58        | 2.63        | 2.63        | 2.60        |
| P <sub>2</sub> O <sub>5</sub> | 31.7         | 33.2         | 31.9         | 30.5         | 32.6         | 31.5         | 28.3         | 33.5         | 32.5         | 27.0        | 32.2        | 28.9        | 30.8        |
| S                             | 0.85         | 0.94         | 0.66         | 0.72         | 0.80         | 0.91         | 0.63         | 0.90         | 0.84         | 0.49        | 0.76        | 0.50        | 0.51        |
| SO <sub>3</sub>               | 2.12         | 2.35         | 1.65         | 1.80         | 2.00         | 2.27         | 1.57         | 2.25         | 2.10         | 1.22        | 1.90        | 1.25        | 1.27        |
| CO <sub>2</sub>               | 7.91         | 7.91         | 6.71         | 6.19         | 7.59         | 7.95         | 5.35         | 7.11         | 7.99         | 3.84        | 5.48        | 4.44        | 4.76        |
| LOI <sup>2</sup>              | 10.7         | 10.5         | 8.30         | 8.95         | 9.65         | 11.7         | 9.15         | 8.00         | 9.00         | 7.67        | 8.01        | 8.05        | 5.88        |
| H <sub>2</sub> O <sup>+</sup> | --           | --           | --           | --           | --           | --           | --           | --           | --           | 2.45        | 2.34        | 2.34        | 1.81        |
| Ag (ppm)                      | --           | --           | --           | --           | --           | --           | --           | --           | --           | --          | --          | --          | --          |
| As                            | --           | --           | --           | --           | --           | --           | --           | --           | --           | --          | --          | --          | --          |
| Ba                            | 278          | 267          | 326          | 543          | 267          | 264          | 2140         | 226          | 195          | --          | --          | --          | --          |
| Be                            | --           | --           | --           | --           | --           | --           | --           | --           | --           | --          | --          | --          | --          |
| Bi                            | --           | --           | --           | --           | --           | --           | --           | --           | --           | --          | --          | --          | --          |
| Cd                            | 7.8          | 0.61         | 0.14         | 0.25         | 0.53         | 0.83         | 0.15         | 0.30         | 0.27         | --          | --          | --          | --          |
| Cl                            | 330          | 360          | 550          | 390          | 430          | 300          | 410          | 470          | 450          | 50          | 120         | 700         | 80          |
| Co                            | 13           | 10           | 4            | 10           | 18           | 23           | 7            | 6            | 9            | --          | --          | --          | --          |
| Cr                            | 25           | 14           | 12           | 14           | 14           | 26           | 18           | 20           | 9            | --          | --          | --          | --          |
| Cs                            | --           | --           | --           | --           | --           | --           | --           | --           | --           | --          | --          | --          | --          |
| Cu                            | 34           | 31           | 61           | 89           | 20           | 34           | 33           | 15           | 25           | --          | --          | --          | --          |
| F                             | 36,700       | 38,600       | 39,300       | 37,500       | 41,000       | 36,000       | 39,600       | 42,000       | 43,100       | 31,800      | 33,800      | 34,800      | 33,800      |
| Ga                            | --           | --           | --           | --           | --           | --           | --           | --           | --           | --          | --          | --          | --          |
| Hf                            | --           | --           | --           | --           | --           | --           | --           | --           | --           | --          | --          | --          | --          |
| In                            | --           | --           | --           | --           | --           | --           | --           | --           | --           | --          | --          | --          | --          |
| Li                            | 2            | 5            | 7            | 5            | 2            | 4            | 10           | 2            | 5            | --          | --          | --          | --          |
| Mo                            | 5            | 6            | 4            | 6            | 1            | 8            | 3            | 5            | 5            | --          | --          | --          | --          |
| Mn                            | 387          | 310          | 155          | 155          | 465          | 465          | 465          | 77           | 75           | 1239        | 775         | 6816        | 232         |
| Nb                            | 1.5          | 1.5          | 1.5          | 1.5          | 1.5          | 1.5          | 2.0          | 1.5          | 1.5          | --          | --          | --          | --          |

Table S1. Cont.

| Sample No.                   | 26 DSR 1 | 26 DSR 2 | 28 DSR 6 | 29 DSR 5 | 50 DSR 3 | 61 DSR 1 | 69 DSO 2 | 80 DSK 6 | 85 DSK 1 | D5-A3-2 | D29-A1-1b | CD14-2D | D12-1A <sup>NA</sup> |
|------------------------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|---------|-----------|---------|----------------------|
| Ni                           | 21       | 17       | 11       | 23       | 19       | 26       | 21       | 9        | 13       | --      | --        | --      | --                   |
| Pb                           | 144      | 197      | 118      | 142      | 171      | 196      | 146      | 91       | 99       | --      | --        | --      | --                   |
| Rb                           | 1.5      | 1.5      | 1.5      | 1.5      | 1.5      | 1.5      | 1.5      | 1.5      | 1.5      | --      | --        | --      | --                   |
| Sb                           | --       | --       | --       | --       | --       | --       | --       | --       | --       | --      | --        | --      | --                   |
| Sc                           | --       | --       | --       | --       | --       | --       | --       | --       | --       | --      | --        | --      | --                   |
| Se                           | --       | --       | --       | --       | --       | --       | --       | --       | --       | --      | --        | --      | --                   |
| Sn                           | --       | --       | --       | --       | --       | --       | --       | --       | --       | --      | --        | --      | --                   |
| Sr                           | 2230     | 2170     | 1410     | 1400     | 1850     | 2580     | 1530     | 1360     | 1500     | 1000    | 1600      | --      | --                   |
| Ta                           | --       | --       | --       | --       | --       | --       | --       | --       | --       | --      | --        | --      | --                   |
| Te                           | --       | --       | --       | --       | --       | --       | --       | --       | --       | --      | --        | --      | --                   |
| Th                           | 0.4      | 0.3      | 0.5      | 0.4      | 0.4      | 0.4      | 1.3      | 0.2      | 0.1      | --      | <4.2      | --      | 11                   |
| Tl                           | --       | --       | --       | --       | --       | --       | --       | --       | --       | --      | --        | --      | --                   |
| U                            | 24       | 21       | 6.9      | 10       | 13       | 30       | 6.5      | 8.8      | 8.2      | --      | 11        | --      | 6.5                  |
| V                            | 40       | 32       | 31       | 35       | 23       | 37       | 50       | 27       | 21       | --      | --        | --      | --                   |
| W                            | --       | --       | --       | --       | --       | --       | --       | --       | --       | --      | --        | --      | --                   |
| Zn                           | 145      | 121      | 52       | 68       | 93       | 205      | 67       | 43       | 38       | --      | --        | --      | --                   |
| Zr                           | 37       | 34       | 56       | 62       | 34       | 38       | 65       | 25       | 20       | --      | --        | --      | --                   |
| La <sup>3</sup>              | 222      | 162      | 372      | 98.4     | 194      | 138      | 133      | 114      | 50.1     | 270     | 7.2       | 240     | 200                  |
| Ce                           | 32.2     | 26.7     | 16.6     | 15.5     | 47.3     | 39.4     | 37.6     | 12.7     | 3.40     | 19      | 2         | 36      | 18                   |
| Pr                           | 30.2     | 19.9     | 49.3     | 13.9     | 24.1     | 17.1     | 15.7     | 10.3     | 3.60     | 35      | 1         | 28      | 20                   |
| Nd                           | 138      | 90.8     | 222      | 64.7     | 112      | 78.7     | 67.9     | 43.4     | 16.0     | 150     | 4.4       | 130     | 87                   |
| Sm                           | 28.4     | 18.1     | 44.5     | 13.8     | 23.0     | 16.2     | 13.1     | 7.60     | 2.90     | 28      | 0.97      | 23      | 14                   |
| Eu                           | 7.62     | 5.06     | 11.8     | 3.79     | 6.21     | 4.47     | 4.26     | 2.05     | 0.78     | 7       | 0.22      | 6.3     | 3.6                  |
| Gd                           | 47.4     | 32.1     | 73.9     | 21.6     | 39.0     | 27.7     | 21.0     | 13.9     | 5.60     | 41      | 1.4       | 39      | 24                   |
| Tb                           | 6.80     | 4.80     | 10.7     | 3.10     | 5.60     | 4.10     | 2.90     | 1.90     | 0.80     | 6.1     | 0.18      | 6.1     | 3.5                  |
| Dy                           | 44.6     | 32.1     | 69.7     | 19.0     | 37.6     | 27.1     | 18.1     | 13.0     | 6.00     | 42      | 1.4       | 44      | 26                   |
| Y                            | 660      | 538      | 976      | 242      | 587      | 415      | 266      | 248      | 145      | --      | --        | --      | --                   |
| Ho                           | 12.1     | 9.19     | 19.2     | 4.92     | 10.5     | 7.56     | 4.82     | 3.83     | 1.89     | 10      | 0.41      | 12      | 7                    |
| Er                           | 35.7     | 28.0     | 57.3     | 14.6     | 31.3     | 22.5     | 14.2     | 12.0     | 6.20     | 31      | 1.2       | 39      | 22                   |
| Tm                           | 5.00     | 4.10     | 8.30     | 2.00     | 4.40     | 3.30     | 2.00     | 1.80     | 0.90     | 4.3     | 0.2       | 5.5     | 2.9                  |
| Yb                           | 29.8     | 25.1     | 52.2     | 12.8     | 26.9     | 19.5     | 12.9     | 10.7     | 5.80     | 27      | 1.3       | 35      | 18                   |
| Lu                           | 5.10     | 4.46     | 8.01     | 2.30     | 4.57     | 3.41     | 2.19     | 1.92     | 1.03     | --      | --        | --      | --                   |
| ΣREY <sup>4</sup>            | 1305     | 1000     | 1992     | 532      | 1153     | 824      | 616      | 497      | 250      | --      | --        | --      | --                   |
| %HREY <sup>5</sup>           | 65       | 68       | 65       | 61       | 65       | 65       | 57       | 62       | 70       | --      | --        | --      | --                   |
| C <sub>en</sub> <sup>6</sup> | 0.16     | 0.20     | 0.05     | 0.16     | 0.29     | 0.34     | 0.35     | 0.18     | 0.14     | 0.08    | 0.29      | 0.19    | 0.13                 |
| C <sub>sn</sub> <sup>6</sup> | 0.12     | 0.15     | 0.04     | 0.12     | 0.22     | 0.26     | 0.27     | 0.14     | 0.10     | 0.06    | 0.22      | 0.14    | 0.10                 |

Table S1. Cont.

| Cruise ID                     | F2-88-HW <sup>7</sup> | SO83 <sup>7</sup> | SO83 <sup>7</sup> | SO83 <sup>7</sup> | SO83 <sup>7</sup> | L-1-74-SC <sup>1</sup> | L-1-74-SC <sup>1</sup> | L-1-74-SC <sup>1</sup> | L-1-74-SC <sup>1</sup> | L-1-74-SC <sup>1</sup> | L-1-74-SC <sup>1</sup> | L-2-76-SC <sup>1</sup> |
|-------------------------------|-----------------------|-------------------|-------------------|-------------------|-------------------|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|
| Water                         | 2695                  | 1459              | 1506              | 1103              | 1080              | 950                    | 950                    | ~700                   | ~700                   | 1000                   | 1000                   | 518                    |
| Depth (m)                     |                       |                   |                   |                   |                   |                        |                        |                        |                        |                        |                        |                        |
| Latitude                      | 18°38.2' N            | 35°20.74' N       | 35°20.76' N       | 23°53.38' N       | 23°53.29' N       | 33°9.18' N             | 33°9.18' N             | 34°1.8' N              | 34°1.8' N              | 32°22.92' N            | 32°22.92' N            | 32°44.7' N             |
| Longitude                     | 155°58.2' W           | 15°18.71' W       | 15°08.35' W       | 20°46.11' W       | 20°45.61' W       | 120°11.1' W            | 120°11.1' W            | 120°32.04' W           | 120°32.04' W           | 119°16.32' W           | 119°16.32' W           | 119°59.28' W           |
| Location                      | C. Pacific            | E. Atlantic       | E. Atlantic       | E. Atlantic       | E. Atlantic       | CA Borderland          | CA Borderland          | CA Borderland          | CA Borderland          | CA Borderland          | CA Borderland          | CA Borderland          |
| Sample No.                    | D12-5                 | 62 GTV 1          | 64 GTV 1          | 118 GTV 6         | 126 GTV 3         | LCB-14-A               | LCB-14-B               | LCB-1-4B               | LCB-1-4C               | LCB-20-6C              | LCB-20-8-B             | CD281-A                |
| Fe (wt %)                     | 0.59                  | 0.76              | 0.61              | 0.55              | 0.12              | 2.89                   | 3.27                   | 1.34                   | 1.15                   | 0.54                   | 0.50                   | 1.30                   |
| Si                            | 3.03                  | 2.74              | 2.52              | 1.31              | 0.64              | 7.06                   | 9.07                   | 3.95                   | 6.26                   | 2.13                   | 0.73                   | 1.43                   |
| Al                            | 0.96                  | 1.05              | 1.15              | 0.48              | 0.24              | 2.14                   | 3.01                   | 0.89                   | 1.12                   | 0.79                   | 0.16                   | 0.25                   |
| Si/Al                         | 3.15                  | 2.61              | 2.19              | 2.73              | 2.67              | 3.29                   | 3.01                   | 4.41                   | 5.61                   | 2.68                   | 4.62                   | 5.61                   |
| Mg                            | 0.25                  | 0.45              | 0.37              | 0.13              | 0.11              | 1.27                   | 1.36                   | 0.75                   | 0.59                   | 0.43                   | 0.45                   | 0.55                   |
| Ca                            | 33.9                  | 33.7              | 34.3              | 36.4              | 37.3              | 25.6                   | 22.8                   | 30.6                   | 28.7                   | 33.2                   | 34.5                   | 33.4                   |
| Na                            | 0.58                  | 0.65              | 0.57              | 0.51              | 0.50              | 1.65                   | 1.85                   | 1.22                   | 1.27                   | 1.31                   | 1.14                   | 1.13                   |
| K                             | 0.48                  | 0.23              | 0.21              | <0.01             | <0.01             | 0.64                   | 0.72                   | 0.40                   | 0.51                   | 0.17                   | 0.15                   | 0.26                   |
| Ti                            | 0.08                  | 0.05              | 0.05              | 0.02              | 0.01              | 0.74                   | 0.89                   | 0.07                   | 0.04                   | 0.10                   | 0.01                   | 0.02                   |
| P                             | 13.2                  | 12.6              | 12.4              | 13.9              | 14.4              | 9.38                   | 8.16                   | 11.6                   | 10.9                   | 12.5                   | 13.2                   | 12.9                   |
| Ca/P                          | 2.58                  | 2.67              | 2.77              | 2.62              | 2.59              | 2.73                   | 2.79                   | 2.65                   | 2.64                   | 2.65                   | 2.61                   | 2.59                   |
| P <sub>2</sub> O <sub>5</sub> | 30.2                  | 28.9              | 28.4              | 31.8              | 33.0              | 21.5                   | 18.7                   | 26.5                   | 24.9                   | 28.7                   | 30.3                   | 29.6                   |
| S                             | 0.52                  | 0.71              | 0.63              | 0.65              | 0.74              | 0.73                   | 0.62                   | 1.13                   | 1.01                   | 1.37                   | 1.15                   | 1.12                   |
| SO <sub>3</sub>               | 1.30                  | 1.77              | 1.57              | 1.62              | 1.85              | 1.82                   | 1.55                   | 2.82                   | 2.52                   | 3.42                   | 2.87                   | 2.80                   |
| CO <sub>2</sub>               | 4.55                  | 6.23              | 7.44              | 6.23              | 6.56              | 4.94                   | 4.34                   | 6.61                   | 6.21                   | 6.58                   | 7.01                   | 7.06                   |
| LOI <sup>2</sup>              | 6.74                  | 8.85              | 10.1              | 8.10              | 7.80              | 10.7                   | 10.2                   | 11.9                   | 10.9                   | 10.5                   | 12.2                   | 11.5                   |
| H <sub>2</sub> O <sup>+</sup> | 1.76                  | --                | --                | --                | --                | 4.80                   | 4.80                   | 5.00                   | 4.60                   | 4.50                   | 5.05                   | 4.70                   |
| Ag (ppm)                      | --                    | --                | --                | --                | --                | 0.14                   | 0.13                   | 0.40                   | 0.16                   | 0.17                   | 0.50                   | 0.53                   |
| As                            | --                    | --                | --                | --                | --                | 7.0                    | 7.0                    | 15                     | 15                     | 9.0                    | 6.0                    | 14                     |
| Ba                            | --                    | 235               | 234               | 264               | 493               | 1290                   | 389                    | 145                    | 304                    | 146                    | 215                    | 1260                   |
| Be                            | --                    | --                | --                | --                | --                | 0.80                   | 0.90                   | 0.40                   | 0.40                   | 0.40                   | 0.30                   | 0.30                   |
| Bi                            | --                    | --                | --                | --                | --                | 0.04                   | 0.05                   | 0.05                   | <0.04                  | <0.04                  | <0.04                  | 0.04                   |
| Cd                            | --                    | 0.51              | 0.48              | 0.25              | 0.32              | 2.3                    | 1.6                    | 5.0                    | 1.9                    | 2.2                    | 7.6                    | 1.6                    |
| Cl                            | 70                    | 220               | 2980              | 450               | 580               | 760                    | 700                    | 780                    | 1270                   | 1790                   | 1110                   | 1430                   |
| Co                            | --                    | 12                | 11                | 13                | 5                 | 11                     | 13                     | 2.8                    | 2.9                    | 5.6                    | 4.0                    | 4.0                    |
| Cr                            | --                    | 25                | 19                | 33                | 11                | 181                    | 161                    | 100                    | 96                     | 114                    | 43                     | 52                     |
| Cs                            | --                    | --                | --                | --                | --                | 1.7                    | 2.0                    | 1.0                    | 0.90                   | 0.20                   | 0.40                   | 0.80                   |
| Cu                            | --                    | 47                | 42                | 44                | 21                | 18                     | 20                     | 20                     | 19                     | 20                     | 19                     | 31                     |
| F                             | 42,400                | 39,200            | 40,600            | 46,000            | 46,000            | 18,500                 | 15,500                 | 8990                   | 22,100                 | 24,900                 | 22,900                 | 22,600                 |
| Ga                            | --                    | --                | --                | --                | --                | 5.4                    | 8.0                    | 3.0                    | 2.8                    | 2.0                    | 1.2                    | 1.8                    |
| Hf                            | --                    | --                | --                | --                | --                | 0.21                   | 0.19                   | 0.12                   | 0.15                   | 0.07                   | 0.12                   | 0.13                   |
| In                            | --                    | --                | --                | --                | --                | 0.03                   | 0.04                   | 0.03                   | <0.02                  | <0.02                  | <0.02                  | <0.02                  |
| Li                            | --                    | 10                | 7                 | 7                 | 5                 | 13                     | 20                     | 4.0                    | 5.0                    | 2.0                    | 2.0                    | 3.0                    |
| Mo                            | --                    | 7                 | 9                 | 7                 | --                | 240                    | 256                    | 88                     | 47                     | 36                     | 17                     | 30                     |
| Mn                            | 155                   | 200               | 300               | 300               | 200               | 6.9                    | 5.5                    | 7.2                    | 9.0                    | 12                     | 5.3                    | 4.0                    |
| Nb                            | --                    | <2                | <2                | <2                | <2                | 2.6                    | 2.4                    | 1.0                    | 1.0                    | 0.80                   | 1.0                    | 0.90                   |

Table S1. Cont.

| Sample No.                    | D12-5 | 62 GTV 1 | 64 GTV 1 | 118 GTV 6 | 126 GTV 3 | LCB-14-A | LCB-14-B | LCB-14B | LCB-14C | LCB-20-6C | LCB-20-8-B | CD281-A |
|-------------------------------|-------|----------|----------|-----------|-----------|----------|----------|---------|---------|-----------|------------|---------|
| Ni                            | --    | 25       | 22       | 27        | 71        | 49       | 49       | 44      | 39      | 42        | 37         | 35      |
| Pb                            | --    | 218      | 172      | 166       | 99        | 7.0      | 7.6      | 3.0     | 3.9     | 3.3       | 2.2        | 3.4     |
| Rb                            | --    | 3.0      | <2       | <2        | <2        | 19       | 23       | 17      | 19      | 4.8       | 5.9        | 12      |
| Sb                            | --    | --       | --       | --        | --        | 1.2      | 1.5      | 1.9     | 2.0     | 1.4       | 3.1        | 3.3     |
| Sc                            | --    | --       | --       | --        | --        | 8.5      | 9.4      | 2.4     | 2.1     | 2.4       | 1.0        | 1.4     |
| Se                            | --    | --       | --       | --        | --        | 2.0      | 2.0      | 4.0     | 3.0     | 3.0       | 4.0        | 4.0     |
| Sn                            | --    | --       | --       | --        | --        | 0.50     | 0.50     | 0.40    | <0.3    | <0.3      | <0.3       | 0.70    |
| Sr                            | --    | 1220     | 1120     | 1230      | 1240      | 1760     | 1560     | 2070    | 2030    | 2340      | 2270       | 2330    |
| Ta                            | --    | --       | --       | --        | --        | 0.23     | 0.12     | 0.15    | 0.18    | 0.13      | 0.17       | 0.13    |
| Te                            | --    | --       | --       | --        | --        | 0.05     | <0.05    | <0.05   | <0.05   | <0.05     | <0.05      | <0.05   |
| Th                            | 11    | 5.5      | 2.6      | 1         | 0.8       | 1.1      | 1.3      | 0.80    | 1.1     | 0.50      | 0.30       | 0.50    |
| Tl                            | --    | --       | --       | --        | --        | 0.34     | 0.31     | 2.5     | 1.9     | 3.2       | 1.6        | 2.0     |
| U                             | 6.8   | 9.1      | 6.9      | 7.9       | 6.3       | 71       | 62       | 85      | 70      | 102       | 73         | 81      |
| V                             | --    | 48       | 45       | 47        | 24        | 143      | 165      | 119     | 56      | 49        | 59         | 64      |
| W                             | --    | --       | --       | --        | --        | 0.60     | 0.50     | 0.30    | 0.40    | 0.30      | 0.40       | 0.40    |
| Zn                            | --    | 63       | 54       | 57        | 39        | 94       | 88       | 55      | 41      | 58        | 50         | 46      |
| Zr                            | --    | 77       | 58       | 26        | 44        | 103      | 141      | 24      | 33      | 18        | 8.8        | 8.0     |
| La <sup>3</sup>               | 230   | 266      | 254      | 184       | 96.5      | 30.3     | 32.6     | 15.8    | 19.1    | 30.7      | 15.1       | 19.8    |
| Ce                            | 32    | 74.0     | 49.9     | 34.7      | 15.5      | 37.0     | 42.6     | 12.5    | 16.2    | 14.2      | 7.00       | 12.6    |
| Pr                            | 28    | 47.8     | 39.8     | 20.0      | 12.0      | 6.81     | 7.39     | 2.62    | 3.49    | 5.50      | 2.05       | 3.06    |
| Nd                            | 120   | 206      | 173      | 83.9      | 51.9      | 26.6     | 29.4     | 10.4    | 13.8    | 22.4      | 7.90       | 12.2    |
| Sm                            | 21    | 46.8     | 37.3     | 16.4      | 10.4      | 5.60     | 6.10     | 2.10    | 2.75    | 4.50      | 1.60       | 2.40    |
| Eu                            | 5.3   | 11.3     | 9.23     | 4.20      | 2.70      | 1.73     | 1.85     | 0.60    | 0.79    | 1.23      | 0.43       | 0.68    |
| Gd                            | 34    | 63.0     | 53.6     | 26.2      | 15.8      | 6.49     | 6.53     | 2.98    | 4.05    | 6.46      | 2.48       | 3.54    |
| Tb                            | 4.8   | 9.30     | 7.70     | 3.70      | 2.30      | 0.97     | 1.00     | 0.49    | 0.64    | 1.00      | 0.38       | 0.53    |
| Dy                            | 36    | 54.6     | 45.9     | 22.7      | 13.7      | 5.97     | 5.92     | 3.09    | 4.15    | 6.34      | 2.63       | 3.74    |
| Y                             | --    | 569      | 523      | 379       | 186       | 63.8     | 62.4     | 41.7    | 53.0    | 78.4      | 40.2       | 51.7    |
| Ho                            | 9.3   | 13.1     | 11.5     | 6.08      | 3.56      | 1.27     | 1.25     | 0.72    | 0.96    | 1.44      | 0.67       | 0.89    |
| Er                            | 28    | 37.6     | 33.6     | 18.3      | 10.6      | 4.02     | 3.89     | 2.42    | 3.16    | 4.55      | 2.25       | 3.02    |
| Tm                            | 3.7   | 5.60     | 4.90     | 2.60      | 1.60      | 0.56     | 0.53     | 0.35    | 0.44    | 0.63      | 0.31       | 0.43    |
| Yb                            | 22    | 35.1     | 30.6     | 16.4      | 10.3      | 3.00     | 3.00     | 2.00    | 2.50    | 3.20      | 1.90       | 2.60    |
| Lu                            | --    | 5.89     | 5.21     | 2.79      | 1.79      | 0.45     | 0.43     | 0.31    | 0.40    | 0.44      | 0.30       | 0.41    |
| ΣREY <sup>4</sup>             | --    | 1445     | 1279     | 821       | 435       | 195      | 205      | 98      | 125     | 181       | 85         | 118     |
| %HREY <sup>5</sup>            | --    | 56       | 57       | 59        | 57        | 45       | 42       | 56      | 56      | 57        | 61         | 57      |
| Ce <sub>cn</sub> <sup>6</sup> | 0.17  | 0.23     | 0.18     | 0.25      | 0.19      | 0.80     | 0.85     | 0.70    | 0.68    | 0.38      | 0.50       | 0.60    |
| Ce <sub>sn</sub> <sup>6</sup> | 0.13  | 0.17     | 0.14     | 0.19      | 0.14      | 0.60     | 0.64     | 0.53    | 0.52    | 0.29      | 0.38       | 0.46    |

Table S1. Cont.

| Cruise ID                     | L-2-76-SC <sup>1</sup> | L-2-76-SC <sup>1</sup> | L-2-76-SC <sup>1</sup> | JSL <sup>1</sup> | JSL <sup>1</sup> | JSL <sup>1</sup> | JSL <sup>1</sup> | JSL <sup>1</sup> | JSL <sup>1</sup> | JSL <sup>1</sup> | JSL <sup>1</sup> | JSL <sup>1</sup> | RC-2306 <sup>1</sup> |
|-------------------------------|------------------------|------------------------|------------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|----------------------|
| Water Depth (m)               | 518                    | 529                    | 529                    | 271              | 271              | 256              | 473              | 502              | 743              | 162              | 576              | 259              | 480                  |
| Latitude                      | 32°44.7' N             | 33°3.18' N             | 33°3.18' N             | 13°30.06' S      | 13°30.06' S      | 13°29.4' S       | 13°30.66' S      | 11°59.9' S       | 11°59.5' S       | 12°00.08' S      | 11°35.74' S      | 13°29.16' S      | 7°36.3' S            |
| Longitude                     | 119°59.28' W           | 120°9' W               | 120°9' W               | 76°48.3' W       | 76°48.3' W       | 76°47.82' W      | 76°54.48' W      | 77°50.76' W      | 77°52.15' W      | 77°35.54' W      | 77°51.99' W      | 76°47.91' W      | 80°38.0' W           |
| Location                      | CA                     | CA                     | CA                     | Peru             | Peru             | Peru             | Peru             | Peru             | Peru             | Peru             | Peru             | Peru             | Peru                 |
|                               | Borderland             | Borderland             | Borderland             | Margin           | Margin           | Margin           | Margin           | Margin           | Margin           | Margin           | Margin           | Margin           | Margin               |
| Sample No.                    | CD281-B                | CD350-A                | CD350-B                | 3350-1a          | 3350-1b          | 3352-4           | 3355-2           | 3363-4           | 3365-2           | 3372-1           | 3365             | 3352-6           | 1-2, GS-1            |
| Fe (wt %)                     | 1.41                   | 1.69                   | 1.91                   | 1.48             | 1.67             | 1.61             | 2.43             | 1.23             | 1.17             | 2.10             | 1.24             | 1.31             | 2.97                 |
| Si                            | 1.50                   | 2.48                   | 2.69                   | 6.26             | 12.8             | 5.84             | 7.01             | 9.21             | 7.53             | 14.6             | 7.29             | 5.05             | 9.07                 |
| Al                            | 0.25                   | 0.40                   | 0.43                   | 1.65             | 3.31             | 1.67             | 1.69             | 2.28             | 1.65             | 3.02             | 1.53             | 1.34             | 1.86                 |
| Si/Al                         | 5.91                   | 6.24                   | 6.19                   | 3.81             | 3.87             | 3.51             | 4.15             | 4.04             | 4.56             | 4.84             | 4.75             | 3.76             | 4.87                 |
| Mg                            | 0.57                   | 0.58                   | 0.55                   | 0.67             | 0.64             | 0.72             | 0.73             | 0.74             | 0.66             | 0.42             | 0.62             | 0.66             | 0.72                 |
| Ca                            | 33.3                   | 32.2                   | 32.1                   | 27.7             | 21.3             | 27.7             | 26.0             | 23.8             | 26.5             | 19.1             | 27.1             | 28.7             | 23.9                 |
| Na                            | 1.09                   | 1.07                   | 1.02                   | 1.31             | 1.60             | 1.30             | 1.22             | 1.40             | 1.22             | 1.59             | 1.22             | 1.22             | 1.05                 |
| K                             | 0.32                   | 0.48                   | 0.49                   | 0.62             | 1.06             | 0.64             | 0.79             | 0.66             | 0.49             | 1.21             | 0.44             | 0.49             | 0.90                 |
| Ti                            | 0.02                   | 0.02                   | 0.02                   | 0.08             | 0.13             | 0.08             | 0.08             | 0.13             | 0.09             | 0.10             | 0.08             | 0.07             | 0.11                 |
| P                             | 13.0                   | 12.3                   | 12.2                   | 10.7             | 7.90             | 10.7             | 9.95             | 9.21             | 10.2             | 7.24             | 10.4             | 11.1             | 9.47                 |
| Ca/P                          | 2.57                   | 2.61                   | 2.63                   | 2.58             | 2.70             | 2.58             | 2.62             | 2.59             | 2.61             | 2.63             | 2.61             | 2.58             | 2.53                 |
| P <sub>2</sub> O <sub>5</sub> | 29.7                   | 28.2                   | 28.0                   | 24.6             | 18.1             | 24.6             | 22.8             | 21.1             | 23.3             | 16.6             | 23.8             | 25.5             | 21.7                 |
| S                             | 1.17                   | 1.09                   | 1.58                   | 1.31             | 1.13             | 1.45             | 1.81             | 0.73             | 1.26             | 2.63             | 1.53             | 1.43             | 0.76                 |
| SO <sub>3</sub>               | 2.92                   | 2.72                   | 3.93                   | 3.27             | 2.82             | 3.62             | 4.52             | 1.82             | 3.15             | 6.55             | 3.82             | 3.57             | 1.90                 |
| CO <sub>2</sub>               | 6.59                   | 7.00                   | 6.72                   | 6.38             | 4.30             | 6.09             | 6.05             | 7.02             | 6.78             | 4.03             | 6.54             | 6.34             | 5.45                 |
| LOI <sup>2</sup>              | 11.5                   | 11.1                   | 10.2                   | 10.6             | 8.33             | 10.7             | 10.6             | 13.3             | 11.5             | 8.07             | 10.8             | 10.9             | 11.3                 |
| H <sub>2</sub> O <sup>+</sup> | 4.80                   | 4.40                   | 4.40                   | 4.30             | 3.70             | 4.50             | 3.80             | 4.80             | 4.60             | 3.50             | 5.10             | 5.20             | 5.40                 |
| Ag (ppm)                      | 0.53                   | 0.25                   | 0.16                   | 0.13             | 0.12             | 0.15             | 0.14             | 0.18             | 0.15             | 0.13             | 0.12             | 0.12             | 0.09                 |
| As                            | 11                     | 15                     | 27                     | 25               | 26               | 31               | 31               | 8.0              | 26               | 81               | 29               | 26               | 7.0                  |
| Ba                            | 905                    | 989                    | 1195                   | 105              | 218              | 101              | 106              | 147              | 116              | 281              | 106              | 84               | 95                   |
| Be                            | 0.40                   | 0.60                   | 0.50                   | 0.70             | 0.70             | 0.70             | 0.50             | 0.50             | 0.50             | 0.85             | 0.40             | 0.40             | 0.50                 |
| Bi                            | <0.04                  | <0.04                  | 0.05                   | 0.05             | 0.05             | 0.06             | 0.04             | 0.06             | 0.04             | 0.08             | 0.06             | 0.06             | 0.08                 |
| Cd                            | 5.8                    | 2.5                    | 6.0                    | 8.2              | 5.6              | 6.7              | 9.5              | 9.5              | 11               | 25               | 10.3             | 9.4              | 3.4                  |
| Cl                            | 990                    | 820                    | 670                    | 1647             | 1007             | 2486             | 1987             | 3037             | 1942             | 1177             | 1750             | 1483             | 1773                 |
| Co                            | 4.5                    | 3.5                    | 7.0                    | 4.9              | 4.8              | 5.5              | 4.3              | 2.9              | 2.8              | 3.6              | 2.7              | 4.4              | 2.9                  |
| Cr                            | 91                     | 119                    | 156                    | 103              | 91               | 116              | 73               | 52               | 56               | 49               | 65               | 87               | 66                   |
| Cs                            | 1.0                    | 1.7                    | 2.0                    | 2.0              | 3.0              | 3.0              | 3.0              | 2.0              | 2.0              | 2.0              | 1.0              | 2.0              | 4.0                  |
| Cu                            | 28                     | 30                     | 28                     | 15               | 15               | 15               | 14               | 12               | 15               | 14               | 12               | 14               | 8.4                  |
| F                             | 25,400                 | 23,100                 | 25,100                 | 21,194           | 18,804           | 24,248           | 19,982           | 19,130           | 19,871           | 18,173           | 26,290           | 29,394           | 24,479               |
| Ga                            | 2.4                    | 3.5                    | 3.1                    | 5.0              | 7.4              | 5.3              | 5.4              | 6.2              | 4.9              | 6.3              | 3.3              | 3.3              | 4.8                  |
| Hf                            | 0.15                   | 0.21                   | 0.24                   | 1.0              | 2.0              | 1.0              | 2.0              | 3.0              | 2.0              | 2.0              | 0.08             | 0.10             | 0.25                 |
| In                            | <0.02                  | <0.02                  | <0.02                  | <0.02            | 0.02             | <0.02            | <0.02            | <0.02            | <0.02            | <0.02            | <0.02            | <0.02            | <0.02                |
| Li                            | 4.0                    | 5.0                    | 6.0                    | 9.0              | 11               | 10               | 11               | 11               | 9.0              | 11               | 7.0              | 8.0              | 14                   |
| Mo                            | 24                     | 22                     | 31                     | 82               | 141              | 88               | 87               | 123              | 93               | 111              | 84               | 71               | 98                   |
| Mn                            | 6.5                    | 4.3                    | 44                     | 10               | 8.5              | 16               | 14               | 6.0              | 19               | 63               | 24               | 9.5              | 2.9                  |
| Nb                            | 0.90                   | 1.1                    | 1.1                    | 2.0              | 3.0              | 2.0              | 2.0              | 3.0              | 2.0              | 3.0              | 2.0              | 2.0              | 3.0                  |

Table S1. Cont.

| Sample No.                    | CD281-B | CD350-A | CD350-B | 3350-1a | 3350-1b | 3352-4 | 3355-2 | 3363-4 | 3365-2 | 3372-1 | 3365 | 3352-6 | 1-2, GS-1 |
|-------------------------------|---------|---------|---------|---------|---------|--------|--------|--------|--------|--------|------|--------|-----------|
| Ni                            | 45      | 41      | 55      | 49      | 40      | 59     | 81     | 24     | 46     | 43     | 28   | 34     | 21        |
| Pb                            | 3.8     | 3.4     | 4.2     | 7.7     | 8.3     | 5.6    | 5.0    | 6.5    | 5.4    | 9.8    | 4.2  | 4.7    | 6.4       |
| Rb                            | 14      | 23      | 23      | 25      | 43      | 27     | 33     | 27     | 20     | 49     | 18   | 21     | 39        |
| Sb                            | 4.0     | 3.5     | 4.0     | 1.0     | 1.1     | 1.0    | 2.1    | 0.68   | 0.85   | 3.9    | 1.1  | 1.0    | 1.1       |
| Sc                            | 1.4     | 1.9     | 2.0     | 2.9     | 3.8     | 2.9    | 3.1    | 3.2    | 2.7    | 2.8    | 2.3  | 2.3    | 2.6       |
| Se                            | 4.0     | 4.0     | 6.0     | 4.0     | 3.0     | 3.0    | 4.0    | 3.0    | 3.0    | 5.0    | 3.0  | 3.0    | 2.0       |
| Sn                            | <0.3    | 0.50    | <0.3    | 0.40    | 0.60    | 0.40   | 0.50   | 0.60   | 0.60   | 0.60   | 0.90 | 0.50   | 0.90      |
| Sr                            | 2270    | 2130    | 1955    | 1942    | 1522    | 1975   | 1862   | 1724   | 1980   | 1330   | 1848 | 1922   | 1453      |
| Ta                            | 0.13    | 0.12    | 0.11    | 0.10    | 0.07    | 0.07   | 0.12   | <0.05  | <0.05  | 0.15   | 0.17 | 0.14   | 0.22      |
| Te                            | <0.05   | <0.05   | 0.06    | 0.13    | 0.10    | 0.10   | <0.05  | <0.05  | <0.05  | 0.07   | 0.05 | 0.05   | <0.05     |
| Th                            | 0.50    | 0.50    | 0.55    | 2.3     | 3.7     | 2.7    | 2.3    | 3.2    | 2.3    | 4.8    | 2.5  | 2.4    | 2.9       |
| Tl                            | 2.6     | 1.1     | 3.3     | 4.9     | 4.0     | 6.7    | 2.9    | 0.78   | 1.5    | 3.1    | 1.5  | 5.1    | 0.76      |
| U                             | 94      | 142     | 285     | 140     | 123     | 123    | 133    | 91     | 106    | 177    | 85   | 123    | 48        |
| V                             | 110     | 126     | 122     | 69      | 80      | 61     | 72     | 67     | 55     | 70     | 40   | 48     | 58        |
| W                             | 0.50    | 0.50    | 0.30    | 0.60    | 0.40    | 0.40   | 0.40   | 0.30   | 0.30   | 0.55   | 0.50 | 0.40   | 0.70      |
| Zn                            | 48      | 43      | 46      | 50      | 56      | 39     | 40     | 44     | 37     | 42     | 30   | 33     | 31        |
| Zr                            | 8.5     | 13      | 14      | 49      | 90      | 36     | 61     | 95     | 90     | 73     | 91   | 45     | 77        |
| La <sup>3</sup>               | 25.5    | 26.5    | 20.5    | 10.6    | 12.6    | 10.6   | 9.60   | 10.4   | 8.50   | 12.0   | 9.55 | 11.2   | 9.30      |
| Ce                            | 16.0    | 15.1    | 13.8    | 17.4    | 23.5    | 16.6   | 15.2   | 19.0   | 14.7   | 22.2   | 15.2 | 16.9   | 16.5      |
| Pr                            | 4.13    | 4.05    | 3.20    | 2.38    | 2.93    | 2.17   | 2.02   | 2.43   | 1.96   | 2.74   | 2.06 | 2.26   | 2.05      |
| Nd                            | 16.4    | 16.3    | 13.0    | 9.60    | 11.1    | 9.00   | 8.00   | 9.40   | 7.50   | 10.7   | 8.25 | 9.40   | 8.00      |
| Sm                            | 3.30    | 3.30    | 2.60    | 1.90    | 2.20    | 1.80   | 1.60   | 2.00   | 1.60   | 2.20   | 1.60 | 2.00   | 1.50      |
| Eu                            | 0.89    | 0.86    | 0.67    | 0.49    | 0.58    | 0.44   | 0.40   | 0.48   | 0.40   | 0.62   | 0.42 | 0.50   | 0.33      |
| Gd                            | 4.93    | 4.98    | 3.86    | 2.13    | 2.23    | 2.13   | 1.74   | 2.05   | 1.72   | 2.46   | 1.85 | 2.27   | 1.41      |
| Tb                            | 0.76    | 0.77    | 0.59    | 0.34    | 0.35    | 0.31   | 0.28   | 0.30   | 0.27   | 0.37   | 0.29 | 0.35   | 0.24      |
| Dy                            | 5.18    | 5.16    | 3.92    | 2.29    | 2.13    | 2.05   | 1.73   | 1.91   | 1.68   | 2.39   | 1.81 | 2.30   | 1.27      |
| Y                             | 74.0    | 74.7    | 57.0    | 24.2    | 17.4    | 22.6   | 18.3   | 16.8   | 16.1   | 20.4   | 18.5 | 24.2   | 9.60      |
| Ho                            | 1.27    | 1.27    | 0.95    | 0.52    | 0.44    | 0.46   | 0.38   | 0.42   | 0.38   | 0.51   | 0.43 | 0.54   | 0.28      |
| Er                            | 4.27    | 4.34    | 3.18    | 1.55    | 1.31    | 1.39   | 1.21   | 1.26   | 1.13   | 1.51   | 1.38 | 1.70   | 0.83      |
| Tm                            | 0.61    | 0.61    | 0.47    | 0.25    | 0.21    | 0.23   | 0.20   | 0.21   | 0.18   | 0.25   | 0.20 | 0.24   | 0.12      |
| Yb                            | 3.60    | 3.40    | 2.70    | 1.50    | 1.30    | 1.40   | 1.20   | 1.30   | 1.20   | 1.50   | 1.35 | 1.60   | 0.80      |
| Lu                            | 0.58    | 0.54    | 0.43    | 0.26    | 0.23    | 0.23   | 0.21   | 0.22   | 0.21   | 0.27   | 0.21 | 0.24   | 0.12      |
| ΣREY <sup>4</sup>             | 161     | 162     | 127     | 75      | 78      | 71     | 62     | 68     | 58     | 80     | 63   | 76     | 52        |
| %HREY <sup>5</sup>            | 60      | 60      | 58      | 44      | 33      | 44     | 41     | 37     | 40     | 38     | 42   | 45     | 29        |
| Ce <sub>en</sub> <sup>6</sup> | 0.57    | 0.55    | 0.63    | 1.07    | 1.18    | 1.12   | 1.11   | 1.15   | 1.10   | 1.19   | 1.08 | 1.10   | 1.18      |
| Ce <sub>sn</sub> <sup>6</sup> | 0.43    | 0.41    | 0.48    | 0.81    | 0.89    | 0.85   | 0.83   | 0.87   | 0.83   | 0.90   | 0.82 | 0.83   | 0.89      |

Table S1. Cont.

| Cruise ID                     | NA <sup>8</sup>              | NA                           | NA                           | NA                           | NA                           | NA                           | NA                           | NA                           | NA                           | NA                           | NA                           |
|-------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|
| Water Depth (m)               | NA                           | NA                           | NA                           | NA                           | NA                           | NA                           | NA                           | NA                           | NA                           | NA                           | NA                           |
| Latitude                      | NA                           | NA                           | NA                           | NA                           | NA                           | NA                           | NA                           | NA                           | NA                           | NA                           | NA                           |
| Longitude                     | NA                           | NA                           | NA                           | NA                           | NA                           | NA                           | NA                           | NA                           | NA                           | NA                           | NA                           |
| Location                      | Chatham<br>Rise <sup>1</sup> | Chatham<br>Rise <sup>1</sup> | Chatham<br>Rise <sup>1</sup> | Chatham<br>Rise <sup>1</sup> | Chatham<br>Rise <sup>1</sup> | Chatham<br>Rise <sup>1</sup> | Chatham<br>Rise <sup>1</sup> | Chatham<br>Rise <sup>1</sup> | Chatham<br>Rise <sup>1</sup> | Chatham<br>Rise <sup>1</sup> | Chatham<br>Rise <sup>1</sup> |
| Sample No.                    | DD9+2-8                      | DD9+8                        | DD16+2-8                     | DD16+8                       | DD19+2-8                     | DD19+8                       | DD21+2-8                     | DD21+8                       | DD22+2-8                     | DD22+8                       | DD23+2-8                     |
| Fe (wt %)                     | 4.85                         | 3.08                         | 4.79                         | 3.13                         | 4.60                         | 2.60                         | 5.00                         | 2.77                         | 4.18                         | 1.74                         | 3.70                         |
| Si                            | 6.55                         | 5.47                         | 6.36                         | 2.71                         | 6.03                         | 4.17                         | 6.40                         | 1.76                         | 5.66                         | 1.86                         | 5.14                         |
| Al                            | 0.72                         | 1.39                         | 0.68                         | 0.35                         | 0.66                         | 0.59                         | 0.56                         | 0.17                         | 0.66                         | 0.30                         | 0.60                         |
| Si/Al                         | 9.09                         | 3.93                         | 9.31                         | 7.65                         | 9.19                         | 7.04                         | 11.4                         | 10.4                         | 8.55                         | 6.17                         | 8.52                         |
| Mg                            | 0.93                         | 0.76                         | 0.89                         | 0.46                         | 0.84                         | 0.43                         | 0.93                         | 0.39                         | 0.76                         | 0.38                         | 0.71                         |
| Ca                            | 27.0                         | 30.2                         | 27.4                         | 33.1                         | 27.9                         | 32.0                         | 27.3                         | 34.4                         | 28.7                         | 34.8                         | 29.7                         |
| Na                            | 0.65                         | 0.78                         | 0.74                         | 0.69                         | 0.73                         | 0.76                         | 0.65                         | 0.65                         | 0.71                         | 0.67                         | 0.69                         |
| K                             | 1.92                         | 0.62                         | 1.79                         | 0.60                         | 1.71                         | 0.65                         | 1.87                         | 0.47                         | 1.54                         | 0.47                         | 1.37                         |
| Ti                            | 0.012                        | 0.31                         | 0.02                         | 0.01                         | 0.01                         | 0.02                         | 0.01                         | <0.01                        | 0.01                         | <0.01                        | 0.02                         |
| P                             | 9.82                         | 6.24                         | 9.77                         | 9.12                         | 9.86                         | 8.77                         | 9.77                         | 8.55                         | 8.86                         | 8.07                         | 9.03                         |
| Ca/P                          | 2.75                         | 4.83                         | 2.80                         | 3.63                         | 2.83                         | 3.65                         | 2.79                         | 4.02                         | 3.24                         | 4.31                         | 3.29                         |
| P <sub>2</sub> O <sub>5</sub> | 22.5                         | 14.3                         | 22.4                         | 20.9                         | 22.6                         | 20.1                         | 22.4                         | 19.6                         | 20.3                         | 18.5                         | 20.7                         |
| S                             | 0.66                         | 0.53                         | 0.72                         | 0.67                         | 0.76                         | 0.75                         | 0.64                         | 0.9                          | 0.58                         | 0.54                         | 0.68                         |
| SO <sub>3</sub>               | 1.65                         | 1.32                         | 1.80                         | 1.67                         | 1.90                         | 1.87                         | 1.60                         | 2.25                         | 1.45                         | 1.35                         | 1.70                         |
| CO <sub>2</sub>               | 5.51                         | --                           | --                           | --                           | --                           | --                           | 6.12                         | --                           | --                           | --                           | --                           |
| LOI <sup>2</sup>              | 9.97                         | 19.5                         | 10.2                         | 16.8                         | 10.4                         | 16.1                         | 10.3                         | 19.1                         | 13.6                         | 21.3                         | 14.0                         |
| H <sub>2</sub> O <sup>+</sup> | 4.00                         | --                           | --                           | --                           | --                           | --                           | 4.10                         | --                           | --                           | --                           | --                           |
| Ag (ppm)                      | <0.02                        | 0.02                         | <0.02                        | <0.02                        | 0.03                         | <0.02                        | <0.02                        | <0.02                        | 0.02                         | <0.02                        | <0.02                        |
| As                            | 19                           | 15                           | 27                           | 24                           | 39                           | 32                           | 25                           | 23                           | 28                           | 16                           | 30                           |
| Ba                            | 45                           | 185                          | 57                           | 248                          | 50                           | 335                          | 34                           | 115                          | 37                           | 66                           | 46                           |
| Be                            | 1.3                          | 0.70                         | 1.2                          | 0.50                         | 1.3                          | 0.70                         | 1.2                          | 0.40                         | 1.0                          | 0.40                         | 1.2                          |
| Bi                            | 0.07                         | 0.05                         | 0.06                         | <0.04                        | 0.07                         | 0.05                         | 0.06                         | 0.04                         | 0.06                         | <0.04                        | 0.05                         |
| Cd                            | 0.86                         | 0.62                         | 0.47                         | 0.50                         | 0.53                         | 0.72                         | 0.57                         | 0.66                         | 0.44                         | 0.55                         | 0.44                         |
| Cl                            | 340                          | 770                          | 810                          | 830                          | 780                          | 820                          | 420                          | 820                          | 720                          | 1160                         | 490                          |
| Co                            | 7.9                          | 9.7                          | 7.7                          | 5.2                          | 9.7                          | 8.1                          | 8.4                          | 5.5                          | 8.0                          | 5.4                          | 8.2                          |
| Cr                            | 56                           | 76                           | 51                           | 23                           | 51                           | 71                           | 49                           | 17                           | 48                           | 19                           | 44                           |
| Cs                            | 3.0                          | 2.5                          | 2.6                          | 1.1                          | 2.7                          | 1.0                          | 3.3                          | 0.80                         | 2.6                          | 0.70                         | 2.4                          |
| Cu                            | 1.0                          | 11                           | 3.5                          | 4.6                          | 3.6                          | 7.7                          | 9.2                          | 7.0                          | 13                           | 11                           | 4.9                          |
| F                             | 22,600                       | 13,500                       | 24,800                       | 17,400                       | 22,600                       | 18,100                       | 20,800                       | 20,200                       | 20,500                       | 15,900                       | 16,900                       |
| Ga                            | 5.3                          | 4.9                          | 4.9                          | 2.4                          | 4.7                          | 2.6                          | 4.6                          | 1.7                          | 3.9                          | 1.8                          | 3.6                          |
| Hf                            | 0.26                         | 0.34                         | 0.22                         | 0.17                         | 0.21                         | 0.16                         | 0.15                         | 0.11                         | 0.17                         | 0.08                         | 0.15                         |

Table S1. Cont.

| Sample No.                    | DD9+2-8 | DD9+8 | DD16+2-8 | DD16+8 | DD19+2-8 | DD19+8 | DD21+2-8 | DD21+8 | DD22+2-8 | DD22+8 | DD23+2-8 |
|-------------------------------|---------|-------|----------|--------|----------|--------|----------|--------|----------|--------|----------|
| In                            | <0.02   | <0.02 | <0.02    | <0.02  | <0.02    | <0.02  | <0.02    | <0.02  | <0.02    | <0.02  | <0.02    |
| Li                            | 13      | 12    | 12       | 5.0    | 11       | 5.0    | 11       | 3.0    | 9.0      | 4.0    | 8.0      |
| Mo                            | 57      | 324   | 64       | 99     | 65       | 110    | 62       | 80     | 66       | 78     | 69       |
| Mn                            | 2.8     | 3.6   | 2.8      | 2.8    | 3.5      | 7.3    | 2.1      | 3.2    | 3.8      | 1.7    | 3.6      |
| Nb                            | 1.4     | 3.8   | 1.5      | 0.90   | 1.4      | 1.0    | 1.2      | 0.50   | 1.2      | 0.60   | 1.1      |
| Ni                            | 31      | 40    | 30       | 23     | 40       | 53     | 31       | 25     | 39       | 26     | 36       |
| Pb                            | 15      | 7.8   | 14       | 8.4    | 14       | 9.1    | 14       | 7.2    | 20       | 7.0    | 12       |
| Rb                            | 75      | 28    | 70       | 25     | 68       | 26     | 74       | 19     | 60       | 17     | 54       |
| Sb                            | 3.8     | 2.6   | 4.5      | 4.6    | 5.5      | 4.2    | 4.3      | 3.4    | 4.7      | 2.6    | 3.4      |
| Sc                            | 2.6     | 4.2   | 2.2      | 1.4    | 2.2      | 1.3    | 2.3      | 0.90   | 2.0      | 1.4    | 2.3      |
| Se                            | <2      | <2    | <2       | <2     | <2       | <2     | <2       | <2     | <2       | <2     | <2       |
| Sn                            | 5.1     | 0.80  | 0.30     | 0.30   | 0.70     | 1.3    | 2.0      | 0.50   | 3.1      | 0.70   | 0.50     |
| Sr                            | 1110    | 1120  | 1140     | 1330   | 1160     | 1370   | 1110     | 1380   | 1180     | 1410   | 1240     |
| Ta                            | <0.05   | 0.19  | 0.07     | <0.05  | <0.05    | 0.05   | <0.05    | <0.05  | <0.05    | <0.05  | <0.05    |
| Te                            | 0.12    | 0.11  | 0.11     | 0.13   | 0.14     | 0.12   | 0.09     | 0.09   | 0.08     | 0.10   | 0.07     |
| Th                            | 0.20    | 1.0   | 0.30     | 0.30   | 0.30     | 0.50   | <0.2     | <0.2   | 0.30     | <0.2   | 0.30     |
| Tl                            | 0.42    | 0.23  | 0.67     | 0.27   | 1.2      | 1.4    | 0.64     | 0.71   | 1.3      | 1.0    | 1.2      |
| U                             | 92      | 64    | 98       | 130    | 93       | 157    | 111      | 201    | 154      | 282    | 182      |
| V                             | 86      | 94    | 88       | 73     | 89       | 73     | 85       | 66     | 80       | 61     | 71       |
| W                             | 0.40    | 0.50  | 0.40     | 0.70   | 0.50     | 0.70   | 0.30     | 0.50   | 0.30     | 0.40   | 0.20     |
| Zn                            | 31      | 38    | 32       | 26     | 30       | 27     | 30       | 23     | 31       | 21     | 26       |
| Zr                            | 25      | 52    | 24       | 20     | 22       | 38     | 22       | 10     | 23       | 19     | 23       |
| La <sup>3</sup>               | 48.9    | 14.6  | 38.2     | 13.0   | 36.0     | 11.0   | 42.0     | 7.60   | 30.2     | 10.6   | 27.7     |
| Ce                            | 29.8    | 16.9  | 23.4     | 9.10   | 22.4     | 8.50   | 25.8     | 4.10   | 20.7     | 7.30   | 20.2     |
| Pr                            | 5.38    | 2.84  | 4.25     | 1.78   | 4.07     | 1.63   | 4.53     | 1.02   | 3.63     | 1.52   | 3.54     |
| Nd                            | 21.7    | 11.3  | 17.2     | 7.20   | 16.2     | 6.70   | 18.4     | 4.30   | 14.9     | 6.30   | 14.4     |
| Sm                            | 3.60    | 2.20  | 2.80     | 1.20   | 2.70     | 1.20   | 3.00     | 0.80   | 2.50     | 1.10   | 2.50     |
| Eu                            | 0.90    | 0.64  | 0.71     | 0.28   | 0.69     | 0.30   | 0.73     | 0.18   | 0.63     | 0.29   | 0.60     |
| Gd                            | 5.11    | 2.52  | 4.11     | 1.69   | 4.03     | 1.53   | 4.26     | 1.09   | 3.42     | 1.49   | 3.32     |
| Tb                            | 0.73    | 0.35  | 0.59     | 0.24   | 0.57     | 0.23   | 0.61     | 0.16   | 0.50     | 0.22   | 0.49     |
| Dy                            | 4.88    | 2.07  | 3.95     | 1.58   | 3.74     | 1.51   | 4.06     | 0.98   | 3.21     | 1.49   | 3.19     |
| Y                             | 78.1    | 20.8  | 60.9     | 22.5   | 57.7     | 19.0   | 66.4     | 13.6   | 50.4     | 19.8   | 48.6     |
| Ho                            | 1.35    | 0.47  | 1.03     | 0.43   | 1.03     | 0.38   | 1.08     | 0.25   | 0.87     | 0.39   | 0.82     |
| Er                            | 4.09    | 1.37  | 3.08     | 1.30   | 3.08     | 1.18   | 3.28     | 0.82   | 2.69     | 1.16   | 2.56     |
| Tm                            | 0.57    | 0.19  | 0.43     | 0.19   | 0.44     | 0.17   | 0.46     | 0.12   | 0.37     | 0.18   | 0.37     |
| Yb                            | 3.40    | 1.20  | 2.70     | 1.20   | 2.60     | 1.00   | 2.80     | 0.70   | 2.20     | 1.00   | 2.20     |
| Lu                            | 0.53    | 0.17  | 0.41     | 0.18   | 0.40     | 0.14   | 0.41     | 0.10   | 0.33     | 0.15   | 0.33     |
| ΣREY <sup>4</sup>             | 209     | 78    | 164      | 62     | 156      | 54     | 178      | 36     | 137      | 53     | 131      |
| %HREY <sup>5</sup>            | 48      | 38    | 48       | 48     | 48       | 47     | 47       | 50     | 47       | 49     | 48       |
| Ce <sub>cn</sub> <sup>6</sup> | 0.81    | 0.87  | 0.81     | 0.75   | 0.81     | 0.77   | 0.84     | 0.59   | 0.84     | 0.71   | 0.84     |
| Ce <sub>sn</sub> <sup>6</sup> | 0.61    | 0.66  | 0.61     | 0.57   | 0.61     | 0.58   | 0.63     | 0.45   | 0.63     | 0.53   | 0.63     |

Table S1. Cont.

| Cruise ID                     | NA                        | NA                        | NA                        | NA                        | GOS74         | GOS74         | GOS74         | GOS74         | GOS74         | GOS74         | GOS74         | GOS74         |
|-------------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
| Water Depth (m)               | NA                        | NA                        | NA                        | NA                        | 651           | 651           | 423           | 423           | 743           | 743           | 501           | 992           |
| Latitude                      | NA                        | NA                        | NA                        | NA                        | 31°59.7' N    | 31°59.7' N    | 32°10.6' N    | 32°10.6' N    | 30°51.8' N    | 30°51.8' N    | 31°35.9' N    | 32° 35.9' N   |
| Longitude                     | NA                        | NA                        | NA                        | NA                        | 78°15.4' W    | 78°15.4' W    | 78°46.0' W    | 78°46.0' W    | 79°10.1' W    | 79°10.1' W    | 79°04.2' W    | 77° 57.6' W   |
| Location                      | Chatham Rise <sup>1</sup> | Chatham Rise <sup>1</sup> | Chatham Rise <sup>1</sup> | Chatham Rise <sup>1</sup> | Blake Plateau | Blake Plateau | Blake Plateau | Blake Plateau | Blake Plateau | Blake Plateau | Blake Plateau | Blake Plateau |
| Sample No.                    | DD23+8                    | DD24+2-8                  | DD24+2-8C <sup>9</sup>    | DD24+8                    | 2397-A        | 2397-B        | 2399-A        | 2399-B        | 2476-A        | 2476-B        | 2480          | 2485          |
| Fe (wt %)                     | 1.63                      | 2.62                      | 2.61                      | 1.26                      | 1.72          | 3.88          | 3.71          | 2.76          | 0.80          | 1.58          | 3.39          | 2.75          |
| Si                            | 1.69                      | 4.46                      | 4.62                      | 1.33                      | 4.08          | 6.45          | 2.37          | 2.47          | 1.80          | 2.01          | 2.78          | 3.49          |
| Al                            | 0.24                      | 0.78                      | 0.77                      | 0.17                      | 0.79          | 1.28          | 0.38          | 0.31          | 0.58          | 0.79          | 0.76          | 0.51          |
| Si/Al                         | 7.09                      | 5.69                      | 5.98                      | 7.63                      | 5.17          | 5.06          | 6.32          | 7.91          | 3.13          | 2.56          | 3.64          | 6.79          |
| Mg                            | 0.37                      | 0.57                      | 0.59                      | 0.34                      | 0.43          | 0.69          | 0.58          | 0.66          | 0.46          | 0.53          | 0.89          | 0.71          |
| Ca                            | 35.4                      | 31.2                      | 30.9                      | 35.7                      | 32.3          | 27.1          | 32.2          | 32.2          | 34.9          | 33.4          | 30.5          | 30.7          |
| Na                            | 0.66                      | 0.71                      | 0.71                      | 0.63                      | 0.53          | 0.73          | 0.69          | 0.91          | 0.55          | 0.70          | 0.67          | 0.90          |
| K                             | 0.44                      | 1.01                      | 1.02                      | 0.33                      | 0.54          | 1.27          | 0.47          | 0.52          | 0.22          | 0.25          | 0.66          | 0.72          |
| Ti                            | 0.006                     | 0.02                      | 0.02                      | <0.01                     | 0.06          | 0.11          | 0.02          | 0.02          | 0.02          | 0.05          | 0.07          | 0.02          |
| P                             | 8.38                      | 5.45                      | 5.45                      | 8.20                      | 7.94          | 9.25          | 9.38          | 10.9          | 6.76          | 7.46          | 8.42          | 9.86          |
| Ca/P                          | 4.23                      | 5.73                      | 5.67                      | 4.35                      | 4.07          | 2.93          | 3.44          | 2.95          | 5.17          | 4.47          | 3.62          | 3.11          |
| P <sub>2</sub> O <sub>5</sub> | 19.2                      | 12.5                      | 12.5                      | 18.8                      | 18.2          | 21.2          | 21.5          | 25.0          | 15.5          | 17.1          | 19.3          | 22.6          |
| S                             | 0.58                      | 0.49                      | 0.47                      | 0.57                      | 0.53          | 0.65          | 0.80          | 0.96          | 0.51          | 0.63          | 0.72          | 0.79          |
| SO <sub>3</sub>               | 1.45                      | 1.22                      | 1.17                      | 1.42                      | 1.32          | 1.62          | 2.00          | 2.40          | 1.27          | 1.57          | 1.80          | 1.97          |
| CO <sub>2</sub>               | --                        | --                        | --                        | --                        | 16.0          | 6.62          | 12.5          | 8.78          | 20.0          | 16.8          | 13.2          | 10.1          |
| LOI <sup>2</sup>              | 21.1                      | 24.2                      | 24.2                      | 22.2                      | 18.5          | 11.3          | 15.8          | 12.7          | 23.8          | 21.4          | 16.9          | 14.3          |
| H <sub>2</sub> O <sup>+</sup> | --                        | --                        | --                        | --                        | 2.70          | 4.10          | 3.70          | 4.20          | 2.45          | 3.50          | 4.30          | 4.50          |
| Ag (ppm)                      | <0.02                     | 0.02                      | <0.02                     | <0.02                     | 0.03          | 0.03          | <0.02         | <0.02         | <0.02         | 0.02          | 0.03          | <0.02         |
| As                            | 12                        | 18                        | 18                        | 11                        | 25            | 32            | 52            | 35            | 12            | 40            | 59            | 26            |
| Ba                            | 50                        | 50                        | 51                        | 39                        | 72            | 403           | 22            | 27            | 369           | 572           | 114           | 26            |
| Be                            | 0.50                      | 0.60                      | 0.60                      | 0.40                      | 1.0           | 1.9           | 0.80          | 1.1           | 0.50          | 1.0           | 1.5           | 0.90          |
| Bi                            | <0.04                     | 0.05                      | 0.05                      | <0.04                     | 0.07          | 0.15          | 0.10          | 0.08          | 0.07          | 0.41          | 0.93          | <0.04         |
| Cd                            | 0.50                      | 0.24                      | 0.47                      | 0.50                      | 0.51          | 0.19          | 0.45          | 0.18          | 0.76          | 0.67          | 0.79          | 0.23          |
| Cl                            | 810                       | 1630                      | 1450                      | 900                       | 376           | 468           | 427           | 697           | 199           | 328           | 445           | 636           |
| Co                            | 3.9                       | 5.3                       | 5.1                       | 3.0                       | 16            | 53            | 8.9           | 7.6           | 58            | 193           | 280           | 5.6           |
| Cr                            | 18                        | 34                        | 24                        | 15                        | 91            | 236           | 269           | 142           | 16            | 30            | 72            | 103           |
| Cs                            | 0.70                      | 1.7                       | 1.7                       | 0.60                      | <1            | 2.0           | 1.0           | 2.0           | <1            | <1            | 1.0           | 2.0           |
| Cu                            | 5.9                       | 15                        | 17                        | 6.1                       | 5.4           | 14            | 7.6           | 5.4           | 20            | 115           | 105           | 6.8           |
| F                             | 17,300                    | 11,000                    | 11,800                    | 14,500                    | 24,690        | 30,268        | 29,274        | 32,171        | 21,912        | 23,386        | 26,538        | 29,303        |
| Ga                            | 1.7                       | 3.0                       | 3.1                       | 1.5                       | 3.0           | 4.6           | 2.8           | 3.0           | 2.3           | 3.3           | 3.6           | 2.9           |
| Hf                            | 0.12                      | 0.10                      | 0.12                      | 0.09                      | 0.15          | 0.27          | 0.17          | 0.19          | 0.13          | 0.51          | 0.21          | 0.24          |
| In                            | <0.02                     | <0.02                     | <0.02                     | <0.02                     | <0.02         | <0.02         | <0.02         | <0.02         | <0.02         | <0.02         | 0.02          | <0.02         |
| Li                            | 3.0                       | 9.0                       | 8.0                       | 3.0                       | 11            | 13            | 7.0           | 9.0           | 9.0           | 13            | 22            | 8.0           |
| Mo                            | 87                        | 75                        | 79                        | 80                        | 1239          | 2711          | 310           | 232           | 6583          | 8597          | 11540         | 310           |
| Mn                            | 1.6                       | 2.7                       | 0.94                      | 1.7                       | 8.0           | 9.0           | 9.8           | 6.0           | 16            | 24            | 30            | 3.5           |
| Nb                            | 0.50                      | 1.2                       | 1.1                       | 0.50                      | 2.0           | 4.0           | 1.0           | 1.0           | 2.0           | 6.0           | 8.0           | 1.0           |

Table S1. Cont.

| Sample No.                    | DD23+8 | DD24+2-8 | DD24+2-8C | DD24+8 | 2397-A | 2397-B | 2399-A | 2399-B | 2476-A | 2476-B | 2480 | 2485 |
|-------------------------------|--------|----------|-----------|--------|--------|--------|--------|--------|--------|--------|------|------|
| Ni                            | 18     | 25       | 19        | 15     | 45     | 103    | 79     | 57     | 110    | 620    | 851  | 26   |
| Pb                            | 6.7    | 20       | 16        | 5.2    | 11     | 16     | 9.7    | 6.8    | 9.9    | 40     | 39   | 4.9  |
| Rb                            | 16     | 39       | 39        | 12     | 22     | 46     | 21     | 28     | 6.6    | 6.8    | 27   | 32   |
| Sb                            | 1.6    | 2.0      | 2.0       | 1.1    | 1.6    | 3.8    | 9.9    | 7.7    | 3.0    | 3.4    | 4.0  | 2.7  |
| Sc                            | 1.3    | 2.0      | 2.0       | 1.3    | 2.6    | 4.6    | 2.5    | 2.2    | 2.3    | 7.5    | 7.7  | 2.2  |
| Se                            | <2     | <2       | <2        | <2     | <2     | 2.0    | <2     | <2     | <2     | 3.0    | 3.0  | <2   |
| Sn                            | 0.80   | 7.5      | 3.2       | 0.60   | 0.30   | 0.50   | 0.30   | 0.30   | <0.3   | 0.40   | 0.80 | <0.3 |
| Sr                            | 1480   | 2660     | 2580      | 1440   | 1241   | 1347   | 1570   | 1990   | 1001   | 1361   | 1420 | 1638 |
| Ta                            | <0.05  | <0.05    | <0.05     | <0.05  | 0.21   | 0.20   | 0.16   | 0.15   | 0.10   | 0.18   | 0.17 | 0.14 |
| Te                            | 0.06   | 0.08     | 0.08      | <0.05  | 0.15   | 0.95   | 0.32   | 0.31   | 0.40   | 1.2    | 2.7  | 0.12 |
| Th                            | <0.2   | 0.70     | 0.60      | <0.2   | 1.8    | 3.3    | 1.1    | 0.90   | 0.50   | 1.6    | 4.9  | 1.2  |
| Tl                            | 0.30   | 0.65     | 0.63      | 0.16   | 0.04   | 0.09   | 0.05   | 0.03   | 1.2    | 1.2    | 1.3  | 0.09 |
| U                             | 222    | 104      | 100       | 334    | 285    | 69     | 43     | 81     | 5.3    | 7.5    | 29   | 87   |
| V                             | 48     | 51       | 47        | 55     | 127    | 142    | 174    | 124    | 37     | 84     | 115  | 72   |
| W                             | 0.30   | 0.30     | 0.10      | <0.1   | 0.90   | 2.5    | 1.7    | 1.3    | 3.4    | 13     | 7.0  | 0.50 |
| Zn                            | 20     | 26       | 30        | 17     | 39     | 95     | 91     | 62     | 41     | 109    | 160  | 39   |
| Zr                            | 16     | 23       | 22        | 17     | 75     | 151    | 25     | 22     | 34     | 97     | 84   | 34   |
| La <sup>3</sup>               | 11.0   | 20.8     | 20.4      | 8.60   | 32.4   | 70.9   | 44.9   | 37.6   | 34.4   | 131    | 133  | 23.4 |
| Ce                            | 7.70   | 15.8     | 15.5      | 6.10   | 47.9   | 51.8   | 23.4   | 20.8   | 7.60   | 47.4   | 77.8 | 16.3 |
| Pr                            | 1.53   | 2.75     | 2.73      | 1.33   | 5.66   | 9.99   | 6.97   | 5.64   | 4.18   | 19.6   | 22.6 | 3.83 |
| Nd                            | 6.40   | 11.2     | 10.9      | 5.50   | 23.1   | 42.7   | 31.4   | 25.6   | 18.0   | 87.9   | 102  | 17.0 |
| Sm                            | 1.20   | 1.90     | 1.90      | 1.00   | 4.10   | 8.20   | 6.00   | 4.80   | 3.10   | 16.2   | 20.1 | 3.40 |
| Eu                            | 0.29   | 0.47     | 0.47      | 0.24   | 1.10   | 2.15   | 1.71   | 1.36   | 0.88   | 4.53   | 5.23 | 0.90 |
| Gd                            | 1.62   | 2.63     | 2.50      | 1.35   | 5.05   | 11.3   | 8.84   | 7.18   | 4.62   | 23.8   | 27.1 | 4.48 |
| Tb                            | 0.24   | 0.38     | 0.36      | 0.19   | 0.66   | 1.46   | 1.18   | 0.93   | 0.65   | 3.08   | 3.53 | 0.61 |
| Dy                            | 1.53   | 2.40     | 2.32      | 1.25   | 4.33   | 10.0   | 7.84   | 6.49   | 4.54   | 21.7   | 23.1 | 4.17 |
| Y                             | 21.1   | 34.3     | 33.8      | 17.3   | 38.4   | 115    | 87.5   | 72.3   | 57.0   | 231    | 216  | 42.9 |
| Ho                            | 0.39   | 0.63     | 0.61      | 0.33   | 0.87   | 2.24   | 1.69   | 1.42   | 1.02   | 4.64   | 4.69 | 0.89 |
| Er                            | 1.27   | 1.85     | 1.84      | 0.98   | 2.55   | 6.51   | 5.09   | 4.34   | 3.20   | 13.8   | 13.3 | 2.68 |
| Tm                            | 0.18   | 0.26     | 0.26      | 0.15   | 0.38   | 0.97   | 0.78   | 0.66   | 0.49   | 2.05   | 1.91 | 0.39 |
| Yb                            | 1.10   | 1.60     | 1.60      | 0.90   | 2.20   | 5.60   | 4.20   | 3.60   | 2.80   | 11.5   | 10.5 | 2.30 |
| Lu                            | 0.15   | 0.22     | 0.22      | 0.12   | 0.38   | 0.97   | 0.76   | 0.65   | 0.49   | 2.10   | 1.83 | 0.42 |
| ΣREY <sup>4</sup>             | 56     | 97       | 95        | 45     | 169    | 340    | 232    | 193    | 143    | 620    | 663  | 124  |
| %HREY <sup>5</sup>            | 50     | 46       | 46        | 50     | 33     | 46     | 51     | 51     | 53     | 51     | 46   | 48   |
| Ce <sub>cn</sub> <sup>6</sup> | 0.74   | 0.84     | 0.83      | 0.67   | 1.24   | 0.76   | 0.49   | 0.54   | 0.27   | 0.36   | 0.51 | 0.63 |
| Ce <sub>sn</sub> <sup>6</sup> | 0.56   | 0.64     | 0.63      | 0.51   | 0.94   | 0.58   | 0.37   | 0.41   | 0.20   | 0.27   | 0.38 | 0.47 |

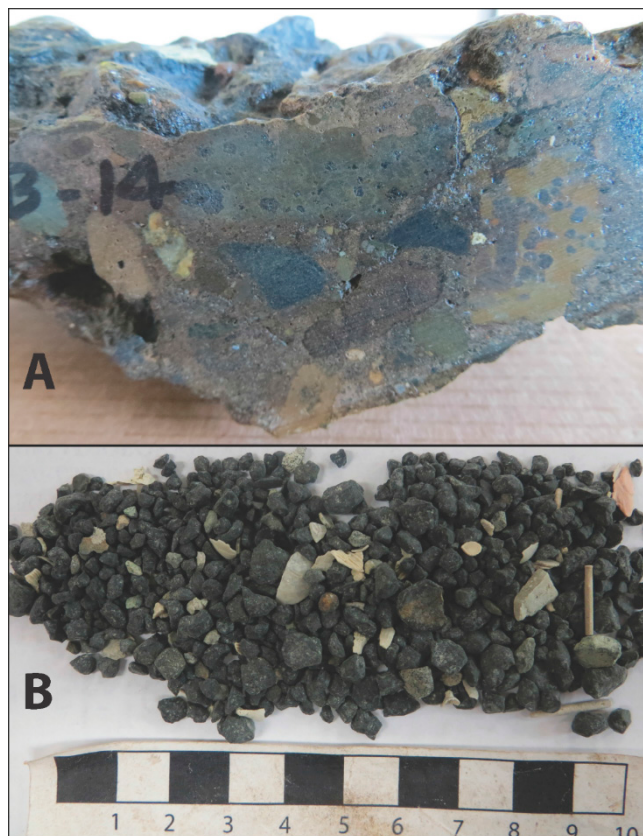
Table S1. Cont.

| Cruise ID                     | CHN46-1       | AT-266        | SO83 <sup>7</sup>  |
|-------------------------------|---------------|---------------|--------------------|
| Water depth (m)               | 875           | 739           | 444–749            |
| Latitude                      | 30°43.8' N    | 31°56.52' N   | 37°45.85' N        |
| Longitude                     | 78°05' W      | 77°25.98' W   | 9°28.45' W         |
| Location                      | Blake Plateau | Blake Plateau | E. Atlantic Margin |
| Sample No.                    | Station 15-2  | D42-4         | 23 GTV II A3       |
| Fe (wt %)                     | 1.94          | 0.92          | 2.70               |
| Si                            | 1.17          | 2.00          | 5.56               |
| Al                            | 0.74          | 0.96          | 0.98               |
| Si/Al                         | 1.60          | 2.08          | 5.67               |
| Mg                            | 0.92          | 0.62          | 0.74               |
| Ca                            | 32.2          | 32.2          | 29.0               |
| Na                            | 0.71          | 0.75          | 0.79               |
| K                             | 0.19          | 0.26          | 0.83               |
| Ti                            | 0.04          | 0.05          | 0.05               |
| P                             | 9.73          | 8.33          | 10.1               |
| Ca/P                          | 3.31          | 3.87          | 2.87               |
| P <sub>2</sub> O <sub>5</sub> | 22.3          | 19.1          | 23.1               |
| S                             | 0.66          | 0.55          | 0.58               |
| SO <sub>3</sub>               | 1.65          | 1.37          | 1.45               |
| CO <sub>2</sub>               | 11.4          | 14.5          | 10.2               |
| LOI <sup>2</sup>              | 14.7          | 17.7          | 12.8               |
| H <sub>2</sub> O <sup>+</sup> | 4.20          | 3.30          | --                 |
| Ag (ppm)                      | 0.03          | 0.02          | --                 |
| As                            | 46            | 21            | --                 |
| Ba                            | 320           | 1301          | 203                |
| Be                            | 0.90          | 0.80          | --                 |
| Bi                            | 0.34          | 0.34          | --                 |
| Cd                            | 1.3           | 1.0           | 0.19               |
| Cl                            | 895           | 591           | 180                |
| Co                            | 338           | 302           | 5.5                |
| Cr                            | 12            | 18            | 44                 |
| Cs                            | <1            | <1            | --                 |
| Cu                            | 290           | 154           | 5.0                |
| F                             | 28,494        | 26,119        | 35,400             |
| Ga                            | 5.0           | 4.2           | --                 |
| Hf                            | 0.50          | 0.37          | --                 |
| In                            | <0.02         | <0.02         | --                 |
| Li                            | 31            | 20            | 12                 |
| Mo                            | 29508         | 30051         | 300                |
| Mn                            | 72            | 45            | 3.0                |
| Nb                            | 4.0           | 4.0           | 4.0                |
| Ni                            | 1738          | 1037          | 28                 |

Table S1. Cont.

| Sample No.                    | Station 15-2 | D42-4 | 23 GTV II A3 |
|-------------------------------|--------------|-------|--------------|
| Pb                            | 33           | 23    | 123          |
| Rb                            | 7.0          | 8.0   | 34           |
| Sb                            | 6.8          | 6.5   | --           |
| Sc                            | 11           | 8.3   | --           |
| Se                            | 3.0          | 2.0   | --           |
| Sn                            | 0.50         | 0.40  | --           |
| Sr                            | 1139         | 1048  | 1340         |
| Ta                            | 0.18         | 0.15  | --           |
| Te                            | 1.9          | 1.2   | --           |
| Th                            | 1.9          | 2.4   | 1.6          |
| Tl                            | 9.5          | 7.2   | --           |
| U                             | 10           | 6.5   | 112          |
| V                             | 135          | 120   | 89           |
| W                             | 30           | 17    | --           |
| Zn                            | 128          | 108   | 54           |
| Zr                            | 106          | 100   | 40           |
| La <sup>3</sup>               | 106          | 97.7  | 21.0         |
| Ce                            | 35.1         | 33.6  | 25.8         |
| Pr                            | 14.8         | 14.5  | 3.65         |
| Nd                            | 67.2         | 64.7  | 15.7         |
| Sm                            | 12.6         | 12.4  | 3.60         |
| Eu                            | 3.45         | 3.20  | 0.86         |
| Gd                            | 19.5         | 17.6  | 4.70         |
| Tb                            | 2.67         | 2.33  | 0.70         |
| Dy                            | 19.5         | 16.3  | 3.95         |
| Y                             | 257          | 182   | 46.0         |
| Ho                            | 4.76         | 3.56  | 0.95         |
| Er                            | 14.8         | 11.2  | 2.70         |
| Tm                            | 2.32         | 1.73  | 0.40         |
| Yb                            | 13.9         | 9.90  | 2.35         |
| Lu                            | 2.52         | 1.81  | 0.39         |
| ΣREY <sup>4</sup>             | 576          | 473   | 110          |
| %HREY <sup>5</sup>            | 59           | 53    | 34           |
| Ce <sub>cn</sub> <sup>6</sup> | 0.35         | 0.34  | 1.04         |
| Ce <sub>sn</sub> <sup>6</sup> | 0.26         | 0.26  | 0.78         |

<sup>1</sup> Mn values obtained through 4-acid digest ICP-MS rather than XRF with a detection limit of 2 ppm<sup>2</sup> %LOI = Loss on ignition at 1000° C; H<sub>2</sub>O<sup>+</sup> = structural water; <sup>3</sup> REY %Error is better than 5.5; precision is better than 6.5%; <sup>4</sup> ΣREY = Sum of rare earth elements plus yttrium; <sup>5</sup> %HREY (Eu-Lu) of the total sum of REY; <sup>6</sup> Ce<sub>cn</sub> = Ce anomaly using chondrite-normalized values; Ce<sub>sn</sub> = Ce anomaly using PAAS-normalized values; ; <sup>7</sup> Treated with 0.5 M triammonium citrate and 30% H<sub>2</sub>O<sub>2</sub> to remove calcite and organic matter; removed from statistics; <sup>8</sup> NA = data not available; <sup>9</sup> DD24+2-8C: control sample, shells removed; C. Pacific means central Pacific.



**Figure S1.** Photographs of continental margin phosphorites: (A) A pervasively Carbonate Fluorapatite (CFA)-replaced breccia, California margin; field of view represents 14 cm; (B) Phosphorite gravel with shell fragments from Chatham Rise.

**Table S2.** Statistics of phosphorite deposits from continental margins <sup>1</sup>.

| <b>Element</b>                    | <b>N</b> | <b>Mean</b> | <b>Median</b> | <b>StDev</b> | <b>Min</b> | <b>Max</b> |
|-----------------------------------|----------|-------------|---------------|--------------|------------|------------|
| <b>Fe (wt %)</b>                  | 45       | 2.34        | 1.94          | 1.21         | 0.50       | 5.00       |
| <b>Si</b>                         | 45       | 4.77        | 4.46          | 3.07         | 0.73       | 14.6       |
| <b>Al</b>                         | 45       | 1.00        | 0.76          | 0.79         | 0.16       | 3.31       |
| <b>Si/Al</b>                      | 45       | 4.75        | 5.17          | 2.28         | 1.60       | 11.4       |
| <b>Mg</b>                         | 45       | 0.66        | 0.64          | 0.21         | 0.34       | 1.36       |
| <b>Ca</b>                         | 45       | 29.8        | 30.6          | 3.91         | 19.1       | 35.7       |
| <b>Na</b>                         | 45       | 0.96        | 0.78          | 0.34         | 0.53       | 1.85       |
| <b>K</b>                          | 45       | 0.72        | 0.60          | 0.47         | 0.15       | 1.92       |
| <b>Ti</b>                         | 45       | <0.09       | <0.04         | 0.17         | <0.01      | 0.89       |
| <b>P</b>                          | 45       | 9.48        | 9.38          | 1.87         | 5.45       | 13.2       |
| <b>Ca/P</b>                       | 45       | 3.15        | 2.80          | 0.88         | 2.53       | 5.73       |
| <b>P<sub>2</sub>O<sub>5</sub></b> | 45       | 21.7        | 21.5          | 4.29         | 12.5       | 30.3       |
| <b>S</b>                          | 45       | 0.92        | 0.75          | 0.43         | 0.47       | 2.63       |
| <b>SO<sub>3</sub></b>             | 45       | 2.29        | 1.87          | 1.07         | 1.17       | 6.55       |
| <b>CO<sub>2</sub></b>             | 32       | 8.24        | 6.62          | 3.98         | 4.03       | 20.0       |
| <b>LOI <sup>2</sup></b>           | 45       | 14.2        | 11.9          | 4.61         | 8.07       | 24.2       |
| <b>H<sub>2</sub>O<sup>+</sup></b> | 32       | 4.28        | 4.40          | 0.69         | 2.45       | 5.40       |
| <b>As (ppm)</b>                   | 45       | 24          | 25            | 15           | 6.0        | 81         |
| <b>Ba</b>                         | 45       | 285         | 115           | 371          | 22         | 1301       |
| <b>Cd</b>                         | 45       | 3.3         | 0.86          | 4.6          | 0.18       | 25         |
| <b>Cl</b>                         | 45       | 1032        | 820           | 604          | 199        | 3037       |
| <b>Co</b>                         | 45       | 32          | 5.5           | 80           | 2.7        | 338        |
| <b>Cr</b>                         | 45       | 77          | 65            | 57           | 12         | 269        |
| <b>Cu</b>                         | 45       | 27          | 14            | 50           | 1.0        | 290        |
| <b>F</b>                          | 45       | 21571       | 22100         | 5291         | 8990       | 32171      |
| <b>Li</b>                         | 45       | 9.4         | 9.0           | 5.7          | 2.0        | 31         |
| <b>Mn</b>                         | 45       | 2094        | 87            | 6460         | 17         | 30051      |
| <b>Mo</b>                         | 45       | 12          | 6.5           | 16           | 0.94       | 72         |
| <b>Ni</b>                         | 45       | 133         | 40            | 320          | 15         | 1738       |
| <b>Pb</b>                         | 45       | 11          | 7.6           | 8.8          | 2.2        | 40         |

Table S2. *Cont.*

| Element                       | N  | Mean | Median | StDev | Min  | Max  |
|-------------------------------|----|------|--------|-------|------|------|
| Rb                            | 45 | 29   | 23     | 19    | 4.8  | 75   |
| Sr                            | 45 | 1639 | 1522   | 441   | 1001 | 2660 |
| U                             | 45 | 115  | 98     | 76    | 5.3  | 334  |
| V                             | 45 | 85   | 73     | 35    | 37   | 174  |
| Zn                            | 45 | 50   | 40     | 31    | 17   | 160  |
| Zr                            | 45 | 48   | 33     | 38    | 8.0  | 151  |
| La                            | 45 | 30.9 | 20.5   | 30.6  | 7.60 | 133  |
| Ce                            | 45 | 21.3 | 16.6   | 14.3  | 4.10 | 77.8 |
| Pr                            | 45 | 4.79 | 3.20   | 4.63  | 1.02 | 22.6 |
| Nd                            | 45 | 20.3 | 13.0   | 21.1  | 4.30 | 102  |
| Sm                            | 45 | 3.85 | 2.50   | 4.04  | 0.80 | 20.1 |
| Eu                            | 45 | 1.03 | 0.64   | 1.09  | 0.18 | 5.23 |
| Gd                            | 45 | 5.25 | 3.42   | 5.80  | 1.09 | 27.1 |
| Tb                            | 45 | 0.74 | 0.50   | 0.75  | 0.16 | 3.53 |
| Dy                            | 45 | 4.93 | 3.21   | 5.23  | 0.98 | 23.1 |
| Y                             | 45 | 58.9 | 42.9   | 57.3  | 9.60 | 257  |
| Ho                            | 45 | 1.13 | 0.87   | 1.13  | 0.25 | 4.76 |
| Er                            | 45 | 3.48 | 2.56   | 3.38  | 0.82 | 14.8 |
| Tm                            | 45 | 0.51 | 0.37   | 0.51  | 0.12 | 2.32 |
| Yb                            | 45 | 2.97 | 2.20   | 2.90  | 0.70 | 13.9 |
| Lu                            | 45 | 0.50 | 0.33   | 0.53  | 0.10 | 2.52 |
| $\Sigma$ REY <sup>3</sup>     | 45 | 161  | 124    | 148   | 35.8 | 663  |
| %HREY <sup>4</sup>            | 45 | 49   | 48     | 7     | 29   | 61   |
| Ce <sub>cn</sub> <sup>5</sup> | 45 | 0.77 | 0.77   | 0.26  | 0.27 | 1.24 |
| Ce <sub>sn</sub> <sup>5</sup> | 45 | 0.58 | 0.58   | 0.20  | 0.20 | 0.94 |

<sup>1</sup> E. Atlantic continental margin sample removed from table; <sup>2</sup> Loss on ignition at 1000 °C; H<sub>2</sub>O\* = structural water; <sup>3</sup>  $\Sigma$ REY = Sum of rare earth elements plus yttrium;<sup>4</sup> %HREY (Eu-Lu) of the total sum of REY; <sup>5</sup> Ce<sub>cn</sub> = Ce anomaly using chondrite-normalized values; Ce<sub>sn</sub> = Ce anomaly using PAAS-normalized values.

**Table S3.** Statistics of all phosphorite deposits from seamounts.

| <b>Element</b>                    | <b>N</b> | <b>Mean</b> | <b>Median</b> | <b>StDev</b> | <b>Min</b> | <b>Max</b> |
|-----------------------------------|----------|-------------|---------------|--------------|------------|------------|
| <b>Fe (wt %)</b>                  | 30       | 0.54        | 0.42          | 0.56         | 0.01       | 2.89       |
| <b>Si</b>                         | 30       | 1.94        | 1.33          | 1.74         | 0.03       | 7.15       |
| <b>Al</b>                         | 30       | 0.66        | 0.46          | 0.59         | 0.02       | 2.12       |
| <b>Si/Al</b>                      | 30       | 2.93        | 2.95          | 0.98         | 1.55       | 6.01       |
| <b>Mg</b>                         | 30       | 0.23        | 0.21          | 0.13         | 0.04       | 0.62       |
| <b>Ca</b>                         | 30       | 35.1        | 36.3          | 2.59         | 26.2       | 37.9       |
| <b>Na</b>                         | 30       | 0.72        | 0.69          | 0.14         | 0.50       | 1.09       |
| <b>K</b>                          | 30       | <0.25       | <0.16         | 0.26         | <0.01      | 0.86       |
| <b>Ti</b>                         | 30       | <0.06       | <0.04         | 0.06         | 0.004      | 0.28       |
| <b>P</b>                          | 30       | 13.2        | 13.4          | 1.09         | 9.95       | 14.6       |
| <b>Ca/P</b>                       | 30       | 2.70        | 2.60          | 0.17         | 2.58       | 3.51       |
| <b>P<sub>2</sub>O<sub>5</sub></b> | 30       | 30.2        | 30.7          | 2.50         | 22.8       | 33.5       |
| <b>S</b>                          | 30       | 0.70        | 0.72          | 0.13         | 0.49       | 0.94       |
| <b>SO<sub>3</sub></b>             | 30       | 1.75        | 1.79          | 0.31         | 1.22       | 2.35       |
| <b>CO<sub>2</sub></b>             | 27       | 5.94        | 6.19          | 1.42         | 3.75       | 7.99       |
| <b>LOI <sup>1</sup></b>           | 30       | 8.89        | 8.20          | 2.11         | 5.88       | 17.5       |
| <b>H<sub>2</sub>O<sup>+</sup></b> | 14       | 2.19        | 2.15          | 0.31         | 1.76       | 2.80       |
| <b>As (ppm)</b>                   | 12       | 5.2         | 5.0           | 1.7          | 3.0        | 9.0        |
| <b>Ba</b>                         | 25       | 461         | 264           | 614          | 20         | 2140       |
| <b>Cd</b>                         | 25       | 0.66        | 0.32          | 1.5          | 0.14       | 7.8        |
| <b>Cl</b>                         | 30       | 781         | 510           | 848          | 50         | 3410       |
| <b>Co</b>                         | 25       | 16          | 10            | 16           | 1.7        | 68         |
| <b>Cr</b>                         | 25       | 20          | 14            | 11           | 7.0        | 51         |
| <b>Cu</b>                         | 25       | 57          | 42            | 45           | 15         | 205        |
| <b>F</b>                          | 30       | 33713       | 34300         | 8038         | 12300      | 46000      |
| <b>Li</b>                         | 25       | <5.9        | <5.0          | 4.2          | <1.0       | 20         |
| <b>Mo</b>                         | 26       | 4.3         | 4.6           | 2.5          | 0.75       | 9.0        |
| <b>Mn</b>                         | 30       | 910         | 310           | 1467         | 46         | 6816       |
| <b>Ni</b>                         | 25       | 68          | 27            | 92           | 9.0        | 366        |

Table S3. Cont.

| Element                             | N  | Mean | Median | StDev | Min   | Max  |
|-------------------------------------|----|------|--------|-------|-------|------|
| <b>Pb</b>                           | 25 | 82   | 91     | 79    | 1.1   | 218  |
| <b>Rb</b>                           | 25 | <5.3 | <2.7   | 5.5   | <0.50 | 18   |
| <b>Sr</b>                           | 27 | 1412 | 1360   | 434   | 724   | 2580 |
| <b>U</b>                            | 28 | 9.5  | 7.5    | 6.1   | 4.7   | 30   |
| <b>V</b>                            | 25 | 34   | 34     | 10    | 21    | 59   |
| <b>Zn</b>                           | 25 | 66   | 54     | 40    | 26    | 205  |
| <b>Zr</b>                           | 25 | 66   | 62     | 44    | 9.5   | 211  |
| <b>La</b>                           | 30 | 149  | 148    | 87.2  | 7.20  | 372  |
| <b>Ce</b>                           | 30 | 23.1 | 18.4   | 16.0  | 2.00  | 74.0 |
| <b>Pr</b>                           | 30 | 19.6 | 16.4   | 13.0  | 1.00  | 49.3 |
| <b>Nd</b>                           | 30 | 85.6 | 73.3   | 57.3  | 4.40  | 222  |
| <b>Sm</b>                           | 30 | 16.8 | 13.9   | 12.1  | 0.97  | 46.8 |
| <b>Eu</b>                           | 30 | 4.50 | 4.00   | 3.06  | 0.22  | 11.8 |
| <b>Gd</b>                           | 30 | 26.6 | 22.8   | 18.0  | 1.40  | 73.9 |
| <b>Tb</b>                           | 30 | 3.79 | 3.30   | 2.62  | 0.18  | 10.7 |
| <b>Dy</b>                           | 30 | 25.4 | 20.9   | 16.7  | 1.40  | 69.7 |
| <b>Y</b>                            | 25 | 337  | 266    | 218   | 38.9  | 976  |
| <b>Ho</b>                           | 30 | 6.57 | 5.50   | 4.36  | 0.41  | 19.2 |
| <b>Er</b>                           | 30 | 20.1 | 17.8   | 12.9  | 1.20  | 57.3 |
| <b>Tm</b>                           | 30 | 2.85 | 2.52   | 1.86  | 0.20  | 8.30 |
| <b>Yb</b>                           | 30 | 18.2 | 16.2   | 11.5  | 1.30  | 52.2 |
| <b>Lu</b>                           | 25 | 2.90 | 2.30   | 1.86  | 0.35  | 8.01 |
| <b>ΣREY</b> <sup>2</sup>            | 25 | 727  | 602    | 456   | 112   | 1992 |
| <b>%HREY</b> <sup>3</sup>           | 25 | 60   | 61     | 6.5   | 47    | 74   |
| <b>Ce<sub>cn</sub></b> <sup>4</sup> | 30 | 0.22 | 0.19   | 0.22  | 0.05  | 1.29 |
| <b>Ce<sub>sn</sub></b> <sup>4</sup> | 30 | 0.17 | 0.14   | 0.16  | 0.04  | 0.98 |

<sup>1</sup> Loss on ignition at 1000 °C; H<sub>2</sub>O<sup>+</sup> = structural water; <sup>2</sup> ΣREY = Sum of rare earth elements plus yttrium; <sup>3</sup> %HREY (Eu-Lu) of the total sum of REY; <sup>4</sup> Ce<sub>cn</sub> = Ce anomaly using chondrite-normalized values; <sup>4</sup> Ce<sub>sn</sub> = Ce anomaly using PAAS-normalized values.

