## Table S1. Al, Ca, B, and Ga concentrations and B isotopes for IRC.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **IRC dataset** | **Sample ID** | **Elev (cm)** | **Al (wt%)** | **Ca (wt%)** | **B**  **(μg/g)** | **Ga (μg/g)** | **δ11B (‰)** |
|  |  |  | ±2% | ±2% | ±5% | ±5% | ±0.2-1% |
| **Stark Shale** | S-62 | 59.18 | 5.28 | 9.38 | 101 | 14.30 | -1.78 |
| S-61 | 57.66 | 5.75 | 8.77 | 113 | 15.40 |  |
| S-60 | 55.88 | 6.37 | 7.52 | 104 | 17.30 |  |
| S-59 | 54.61 | 7.34 | 4.46 | 143 | 19.90 |  |
| S-58 | 53.34 | 7.33 | 3.34 | 128 | 19.75 |  |
| S-57 | 52.20 | 7.53 | 3.00 | 117 | 19.80 | -2.72 |
| S-56 | 50.55 | 7.39 | 2.63 | 146 | 18.25 |  |
| S-55 | 49.53 | 7.86 | 2.73 | 136 | 20.0 |  |
| S-54 | 48.01 | 7.37 | 3.06 | 128 | 19.50 |  |
| S-53 | 47.24 | 7.43 | 3.30 | 145 | 19.65 |  |
| S-52 | 46.48 | 7.18 | 3.90 | 134 | 18.60 |  |
| S-51 | 45.59 | 7.29 | 3.71 | 173 | 19.05 |  |
| S-50 | 44.70 | 7.06 | 3.39 | 128 | 21.3 | -1.75 |
| S-49 | 43.94 | 6.99 | 3.42 | 122 | 19.55 |  |
| S-48 | 43.18 | 6.74 | 3.85 | 147 | 18.65 |  |
| S-47 | 42.29 | 6.12 | 3.97 | 157 | 16.60 |  |
| S-46 | 41.53 | 5.78 | 4.95 | 121 | 16.90 |  |
| S-45 | 40.77 | 5.86 | 3.69 | 137 | 16.55 |  |
| S-44 | 39.88 | 5.71 | 3.44 | 135 | 15.90 |  |
| S-43 | 39.12 | 6.45 | 2.97 | 152 | 16.95 | 0.22 |
| S-42 | 37.85 | 6.19 | 3.27 | 147 | 16.65 |  |
| S-41 | 36.58 | 4.37 | 8.12 | 106 | 14.85 |  |
| S-40 | 35.56 | 5.46 | 4.30 | 111 | 15.70 |  |
| S-39 | 33.53 | 5.44 | 4.15 | 134 | 15.70 |  |
| S-38 | 32.64 | 5.44 | 1.96 | 165 | 17.25 |  |
| S-37 | 31.75 | 6.04 | 0.50 | 127 | 17.30 |  |
| S-36 | 30.99 | 6.18 | 0.38 | 143 | 17.75 | 0.46 |
| S-35 | 30.23 | 6.40 | 0.33 | 155 | 18.00 |  |
| S-34 | 29.21 | 5.71 | 1.29 | 110 | 16.45 |  |
| S-33 | 28.45 | 3.41 | 11.90 | 97 | 12.00 |  |
| S-32 | 27.43 | 5.31 | 5.56 | 113 | 14.20 |  |
| S-31 | 26.42 | 5.72 | 7.46 | 113 | 15.85 |  |
| S-30 | 25.40 | 5.55 | 4.21 | 127 | 15.95 |  |
| S-29 | 24.64 | 5.38 | 1.58 | 131 | 15.75 | 1.25 |
| S-28 | 23.37 | 5.86 | 0.51 | 148 | 17.00 |  |
| S-27 | 22.10 | 6.47 | 0.39 | 134 | 18.25 |  |
| S-26 | 21.08 | 6.37 | 0.50 | 148 | 17.55 |  |
| S-24 | 20.45 | 4.10 | 9.07 | 102 | 13.20 |  |
| S-23 | 19.30 | 5.35 | 6.94 | 114 | 14.85 |  |
| S-22 | 18.03 | 5.84 | 4.65 | 117 | 15.65 |  |
| S-21 | 17.27 | 4.89 | 4.15 | 130 | 13.75 | 0.86 |
| S-19 | 16.26 | 4.87 | 1.87 | 119 | 14.65 |  |
| S-20 | 16.26 | 4.68 | 1.35 | 130 | 14.75 |  |
| S-18 | 14.99 | 3.91 | 3.41 | 109 | 13.10 |  |
| S-17 | 14.22 | 4.01 | 3.38 | 122 | 13.75 |  |
| S-16 | 13.46 | 5.86 | 4.08 | 116 | 15.95 |  |
| S-15 | 12.45 | 5.05 | 4.57 | 108 | 15.35 |  |
| S-13 | 11.18 | 4.90 | 3.69 | 95 | 14.95 |  |
| S-14 | 11.18 | 5.21 | 3.78 | 110 | 15.35 | -0.12 |
| S-12 | 10.41 | 4.34 | 3.28 | 83 | 14.20 |  |
| S-11 | 9.78 | 5.44 | 1.52 | 124 | 16.25 |  |
| S-10 | 9.14 | 5.79 | 1.38 | 114 | 17.15 |  |
| S-9 | 8.38 | 4.14 | 2.70 | 100 | 14.35 |  |
| S-8 | 7.62 | 4.18 | 4.11 | 94 | 13.60 |  |
| S-7 | 6.86 | 4.62 | 5.41 | 97 | 14.00 | 0.06 |
| S-6 | 5.84 | 5.08 | 6.52 | 77 | 14.85 |  |
| S-5 | 5.08 | 4.65 | 7.98 | 91 | 13.15 |  |
| S-4 | 4.32 | 4.35 | 10.25 | 82 | 12.30 |  |
| S-3 | 3.56 | 5.01 | 10.80 | 87 | 13.70 |  |
| S-2 | 2.41 | 7.25 | 2.70 | 110 | 19.90 |  |
| S-1 | 1.27 | 7.36 | 2.01 | 111 | 20.0 | -0.07 |

## Table S2. Al, Ca, B, and Ga concentrations and B isotopes for CC.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **CC dataset** | **Sample ID** | **Elev (m)** | **Al (wt%)** | **Ca (wt%)** | **B**  **(μg/g)** | **Ga (μg/g)** | **δ11B (‰)** |
|  |  |  | ±2% | ±2% | ±5% | ±5% | ±0.2-1% |
| **Above**  **Stark Shale** | CC-697.25 | 212.52 | 8.44 | 0.28 | 89 | 20.4 | -6.09 |
| CC-701.3 | 213.76 | 7.52 | 0.40 | 65 | 14.25 | -3.36 |
| CC-704.15 | 214.62 | 9.13 | 2.03 | 104 | 23.2 | -4.46 |
| CC-715.2 | 217.99 | 7.27 | 1.37 | 72 | 18.75 | -4.56 |
| **Stark Shale** | CC-722.7 | 220.28 | 10.05 | 0.28 | 96 | 29.5 | -6.09 |
| CC-723.2 | 220.43 | 9.89 | 0.28 | 105 | 29.5 |  |
| CC-724.2 | 220.74 | 10.05 | 0.29 | 98 | 30.1 |  |
| CC-725.2 | 221.04 | 10.25 | 0.28 | 100 | 30.4 | -7.40 |
| CC-726.00 | 221.28 | 10.05 | 0.27 | 105 | 27.3 | -6.14 |
| CC-727.2 | 221.65 | 10.20 | 0.36 | 110 | 29.4 |  |
| CC-728.4 | 222.02 | 3.90 | 16.25 | 36 | 9.68 | 0.58 |
| CC-729.2 | 222.26 | 1.45 | 30.5 | 25 | 4.88 | 2.75 |
| CC-729.8 | 222.44 | 1.84 | 22.3 | 18 | 5.29 |  |
| CC-731.2 | 222.87 | 1.09 | 27.0 | 11 | 3.10 | 26.82 |
| CC-731.80 | 223.05 | 1.31 | 22.7 | 26 | 3.26 |  |
| CC-733.2 | 223.48 | 0.24 | 33.4 | 5 | 0.89 | 20.66 |
| CC-733.70 | 223.63 |  |  | 9.88 | 1.31 |  |
| CC-734.4 | 223.85 | 0.38 | 34.5 | 5 | 0.89 |  |
| CC-734.9 | 224.00 | 0.33 | 35.0 | 5 | 0.77 |  |
| CC-735.2 | 224.09 | 0.38 | 33.8 | 7 | 0.87 |  |
| CC-735.3 | 224.12 | 0.82 | 26.2 | 11 | 1.85 | -3.52 |
| CC-735.4 | 224.15 | 0.38 | 31.1 | 5 | 0.82 |  |
| CC-735.50 | 224.18 |  |  | 7.03 | 0.68 |  |
| CC-735.60 | 224.21 |  |  | 27.4 | 4.96 |  |
| CC-735.72 | 224.25 |  |  | 97.4 | 20.1 |  |
| CC-735.8 | 224.27 | 8.39 | 0.36 | 114 | 21.5 |  |
| CC-735.85 | 224.29 |  |  | 143 | 21.1 |  |
| CC-735.9 | 224.30 | 8.38 | 0.45 | 145 | 21.5 |  |
| CC-735.95 | 224.32 | 7.69 | 0.23 | 143 | 19.15 |  |
| CC-736.0 | 224.33 | 8.70 | 0.24 | 147 | 21.8 |  |
| CC-736.05 | 224.35 | 6.52 | 1.77 | 106 | 17.65 |  |
| CC-736.10 | 224.36 |  |  | 101 | 17.4 |  |
| CC-736.15 | 224.38 | 8.91 | 0.20 | 132 | 22.0 | -3.12 |
| CC-736.35 | 224.44 | 7.81 | 1.50 | 116 | 19.10 |  |
| CC-736.55 | 224.50 | 8.54 | 0.25 | 131 | 20.6 |  |
| CC-736.7 | 224.55 | 4.95 | 3.36 | 57 | 14.50 |  |
| CC-736.85 | 224.59 |  |  | 102 | 17.2 |  |
| CC-737.05 | 224.65 | 8.09 | 1.55 | 103 | 20.5 |  |
| CC-737.2 | 224.70 | 8.43 | 0.67 | 124 | 20.9 |  |
| CC-737.25 | 224.71 | 8.51 | 1.00 | 118 | 20.7 |  |
| CC-737.35 | 224.74 | 8.52 | 0.46 | 128 | 21.0 | -3.22 |
| CC-737.40 | 224.76 |  |  | 73.2 | 16.9 |  |
| CC-737.44 | 224.77 | 4.96 | 1.91 | 76 | 15.45 |  |
| CC-737.48 | 224.78 | 5.08 | 1.56 | 85 | 15.65 |  |
| CC-737.52 | 224.80 | 5.48 | 1.63 | 87 | 17.50 |  |
| CC-737.56 | 224.81 | 6.23 | 1.84 | 94 | 19.00 |  |
| CC-737.60 | 224.82 |  |  | 75.6 | 21.0 |  |
| CC-737.70 | 224.85 | 8.49 | 2.51 | 121 | 22.7 |  |
| CC-737.80 | 224.88 | 9.33 | 1.76 | 134 | 23.9 |  |
| CC-737.90 | 224.91 | 9.19 | 1.90 | 125 | 24.1 | -4.10 |
| CC-738.00 | 224.94 |  |  | 105 | 24.7 |  |
| CC-738.10 | 224.97 | 9.77 | 0.13 | 131 | 27.4 |  |
| CC-738.30 | 225.03 | 9.58 | 0.53 | 136 | 27.0 |  |
| CC-738.50 | 225.09 | 9.55 | 1.29 | 121 | 26.2 |  |
| CC-738.70 | 225.16 |  |  | 88.5 | 25.5 |  |
| CC-738.90 | 225.22 | 9.78 | 1.63 | 121 | 27.4 |  |
| CC-739.10 | 225.28 | 9.54 | 0.34 | 122 | 28.2 |  |
| CC-739.30 | 225.34 | 9.16 | 1.08 | 116 | 28.5 |  |
| CC-739.50 | 225.40 | 10.30 | 1.62 | 122 | 27.3 | -3.38 |
| CC-739.70 | 225.46 | 10.55 | 1.02 | 117 | 28.5 |  |
| CC-740.0 | 225.55 | 10.25 | 1.49 | 117 | 29.4 |  |
| CC-740.35 | 225.66 |  |  | 19.2 | 16.1 |  |
| CC-740.6 | 225.73 | 10.35 | 0.13 | 92 | 25.8 |  |
| CC-741.06 | 225.86 | 10.75 | 0.10 | 89 | 27.5 |  |
| CC-741.6 | 226.04 | 10.70 | 0.18 | 110 | 27.9 | -6.13 |
| CC-742.4 | 226.28 | 10.80 | 0.18 | 103 | 28.4 |  |
| CC-743.20 | 226.53 |  |  | 64.8 | 23.4 |  |