Table 1 Thickness (m), proximate analysis (wt. %), and S content (%) of the coal and noncoal samples from the Yudai and Jinqi underground coal mines in the Qiandongbei Coalfield.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Sample | Thickness (m) | Moisture (ad, %) | Ash yield(d, %) | Volatile matter (daf, %) | S (d, %) |
| YD-R | 0.10 |  | 84.5 |  |  |
| YD-01 | 0.15 | 0.9 | 20.6 | 26.9 | 1.2 |
| YD-02 | 0.15 | 1.1 | 16.7 | 19.3 | 1.5 |
| YD-03 | 0.20 | 1.2 | 18.3 | 19.7 | 1.2 |
| YD-04 | 0.10 | 2.9 | 47.7 | 30.0 | 1.5 |
| YD-05 | 0.20 | 4.1 | 24.0 | 21.5 | 7.5 |
| YD-06 | 0.20 | 1.4 | 27.0 | 24.2 | 1.1 |
| YD-F1 | 0.20 |  | 84.2 |  |  |
| YD-F2 | 0.20 |  | 84.5 |  |  |
| YD-F3 | 0.10 |  | 74.9 |  |  |
| JQ-01 | 0.10 | 2.2 | 35.2 | 33.6 | 11.1 |
| JQ-02 | 0.20 | 1.5 | 27.4 | 25.3 | 3.5 |
| JQ-03 | 0.20 | 1.1 | 26.6 | 24.3 | 1.6 |
| JQ-04 | 0.08 | 2.4 | 49.6 | 68.5 | 0.7 |
| JQ-05 | 0.20 | 0.9 | 7.6 | 21.2 | 2.0 |
| JQ-06 | 0.20 | 1.7 | 28.2 | 26.4 | 1.8 |
| JQ-07 | 0.20 | 1.9 | 21.6 | 16.7 | 1.9 |
| JQ-F1 | 0.15 |  | 76.3 |  |  |
| JQ-F2 | 0.15 |  | 86.2 |  |  |
| JQ-F3 | 0.10 |  | 87.5 |  |  |

ad, air-dry basis; d, dry basis; daf, dry and ash-free basis.

Table 2 Mineralogical proportions of the coal and noncoal samples determined by X-Ray Diffraction (XRD) from the Yudai and Jinqi underground coal mines in the Qiandongbei Coalfield (on whole-coal basis; unit in%).

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sample | Illite | Kaolinite | Quartz | Calcite | Siderite | Pyrite | Marcasite | Gypsum | Rozenite | Jarosite | Anatase |
| YD-R | 34.2 | 4.1 | 14.1 | 29.6 | <dl | 13.4 | <dl | 3.9 | <dl | <dl | 0.8 |
| YD-01 | <dl | 1.1 | 2.9 | 16.6 | <dl | <dl | <dl | <dl | <dl | <dl | <dl |
| YD-02 | <dl | 11.3 | 1.4 | 3.6 | <dl | <dl | <dl | 0.4 | <dl | <dl | <dl |
| YD-03 | <dl | 17.4 | <dl | <dl | <dl | <dl | <dl | 0.9 | <dl | <dl | <dl |
| YD-04 | <dl | 44.9 | <dl | <dl | <dl | 0.8 | <dl | 0.5 | <dl | 0.9 | 0.6 |
| YD-05 | <dl | 10.6 | <dl | <dl | <dl | 4.6 | <dl | 3.5 | 5.3 | <dl | <dl |
| YD-06 | <dl | 25.4 | <dl | <dl | <dl | <dl | <dl | 1.6 | <dl | <dl | <dl |
| YD-F1 | <dl | 97.5 | <dl | <dl | <dl | 0.9 | <dl | <dl | <dl | <dl | 1.6 |
| YD-F2 | <dl | 95.4 | <dl | <dl | <dl | 2.7 | <dl | <dl | <dl | <dl | 1.9 |
| YD-F3 | <dl | 57.0 | <dl | <dl | 11.1 | 30.3 | <dl | <dl | <dl | <dl | 1.6 |
| JQ-01 | <dl | 14.2 | 3.9 | <dl | <dl | 13.5 | 2.7 | <dl | 0.9 | <dl | <dl |
| JQ-02 | <dl | 15.8 | 6.4 | <dl | <dl | 2.8 | 1.4 | <dl | 1.0 | <dl | <dl |
| JQ-03 | <dl | 25.9 | 0.7 | <dl | <dl | <dl | <dl | <dl | <dl | <dl | <dl |
| JQ-04 | 3.2 | 46.0 | <dl | <dl | <dl | <dl | <dl | 0.6 | <dl | <dl | <dl |
| JQ-05 | <dl | 7.5 | <dl | 0.2 | <dl | <dl | <dl | <dl | <dl | <dl | <dl |
| JQ-06 | 0.5 | 27.2 | <dl | <dl | <dl | <dl | <dl | 0.5 | <dl | <dl | <dl |
| JQ-07 | 0.2 | 21.3 | <dl | <dl | <dl | 0.1 | <dl | <dl | <dl | <dl | <dl |
| JQ-F1 | <dl | 93.8 | 3.0 | <dl | <dl | <dl | <dl | 1.9 | <dl | <dl | 1.3 |
| JQ-F2 | <dl | 63.7 | 28.6 | <dl | <dl | 1.0 | <dl | 3.8 | <dl | <dl | 2.9 |
| JQ-F3 | <dl | 60.0 | 33.3 | <dl | <dl | <dl | <dl | 4.0 | <dl | <dl | 2.7 |

<dl, below detection limit.

Table 3 Major-element oxides (%) and trace element concentrations (μg/g) of the coal and noncoal samples from the Yudai underground coal mine (on whole-coal basis).

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sample | YD-R | YD-01 | YD-02 | YD-03 | YD-04 | YD-05 | YD-06 | YD-F1 | YD-F2 | YD-F3 |
| SiO2 | 25 | 3.4 | 6.7 | 8.1 | 22 | 4.9 | 12 | 43 | 40 | 19 |
| TiO2 | 1.2 | 0.14 | 0.44 | 0.37 | 0.60 | 0.33 | 0.36 | 1.8 | 2.2 | 2.4 |
| Al2O3 | 10 | 1.7 | 6.3 | 8.0 | 21 | 5.1 | 9.1 | 35 | 34 | 17 |
| Fe2O3 | 16 | 1.03 | 1.14 | 0.74 | 1.8 | 9.2 | 1.1 | 1.4 | 5.9 | 31 |
| MgO | 0.78 | 0.37 | 0.12 | 0.18 | 0.45 | 0.09 | 0.23 | 0.22 | 0.19 | 0.16 |
| CaO | 14 | 12 | 1.5 | 0.34 | 0.22 | 0.23 | 0.28 | 0.20 | 0.16 | 0.73 |
| Na2O | 0.33 | 0.02 | 0.04 | 0.04 | 0.07 | 0.01 | 0.04 | 0.01 | 0.01 | 0.01 |
| K2O | 1.8 | 0.08 | 0.13 | 0.36 | 0.84 | 0.15 | 0.53 | 0.35 | 0.22 | 0.05 |
| Li | 21 | 7.6 | 29 | 50 | 77 | 40 | 102 | 267 | 335 | 200 |
| Be | 2.2 | 5.0 | 11 | 15 | 14 | 8.8 | 9.1 | 5.0 | 4.5 | 2.3 |
| P | 71 | 16 | 63 | 175 | 175 | 178 | 154 | 250 | 190 | 170 |
| Sc | 13 | 3.6 | 2.2 | 4.0 | 5.6 | 2.5 | 6.2 | 25 | 24 | 15 |
| V | 201 | 110 | 32 | 49 | 58 | 63 | 77 | 200 | 157 | 313 |
| Cr | 105 | 32 | 20 | 31 | 25 | 29 | 32 | 141 | 158 | 135 |
| Mn | 1131 | 227 | 28 | 9.1 | 14 | 12 | 9.2 | 23 | 310 | 341 |
| Co | 22 | 1.6 | 2.7 | 3.3 | 10 | 13 | 4.1 | 2.1 | 5.4 | 26 |
| Ni | 56 | 5.0 | 4.3 | 4.1 | 12 | 19 | 27 | 44 | 96 | 192 |
| Cu | 48 | 3.3 | 13 | 17 | 16 | 37 | 29 | 13 | 57 | 104 |
| Zn | 77 | 18 | 218 | 307 | 28 | 22 | 35 | 16 | 16 | 27 |
| Ga | 15 | 5.5 | 13 | 21 | 33 | 15 | 22 | 76 | 59 | 28 |
| Ge | 0.80 | 1.1 | 4.3 | 4.6 | 4.4 | 5.3 | 6.6 | 3.2 | 2.1 | 1.1 |
| As | 38 | 2.5 | 3.0 | 4.1 | 10 | 28 | 6.0 | 3.8 | 17 | 46 |
| Se | 32 | 4.6 | 12 | 11 | 18 | 31 | 11 | 10 | 22 | 41 |
| Rb | 25 | 1.0 | 1.8 | 7.2 | 15 | 3.2 | 10 | 4.8 | 3.2 | 0.9 |
| Sr | 1547 | 312 | 112 | 124 | 315 | 78 | 219 | 182 | 116 | 91 |
| Y | 22 | 34 | 57 | 75 | 161 | 81 | 129 | 70 | 35 | 36 |
| Zr | 238 | 349 | 561 | 679 | 1614 | 447 | 1268 | 1646 | 1117 | 530 |
| Nb | 42 | 30 | 71 | 84 | 148 | 50 | 102 | 226 | 60 | 69 |
| Mo | 16 | 3.6 | 1.9 | 3.7 | 4.5 | 11 | 2.5 | 3.2 | 7.2 | 19 |
| Sn | 5.3 | 4.6 | 4.0 | 4.3 | 6.6 | 3.5 | 8.5 | 13 | 13 | 6.6 |
| Cs | 1.2 | <dl | <dl | <dl | 1.3 | <dl | 1.3 | 0.59 | 0.58 | <dl |
| Ba | 35 | 3.9 | 4.8 | 17 | 20 | 6.9 | 21 | 15 | 16 | 5.4 |
| La | 60 | 14 | 47 | 163 | 143 | 169 | 132 | 76 | 32 | 60 |
| Ce | 123 | 28 | 108 | 318 | 300 | 343 | 293 | 243 | 116 | 199 |
| Pr | 14 | 3.1 | 11 | 32 | 30 | 36 | 28 | 22 | 10 | 15 |
| Nd | 50 | 12 | 39 | 118 | 109 | 133 | 101 | 85 | 38 | 55 |
| Sm | 9.4 | 3.8 | 8.8 | 24 | 24 | 26 | 21 | 18 | 10 | 10 |
| Eu | 1.4 | 0.30 | 0.68 | 1.7 | 1.9 | 1.9 | 1.8 | 2.8 | 1.5 | 1.9 |
| Gd | 6.6 | 4.5 | 8.2 | 20 | 24 | 22 | 19 | 18 | 8.2 | 8.2 |
| Tb | 0.95 | 0.83 | 1.4 | 2.7 | 4.0 | 2.7 | 2.9 | 2.9 | 1.5 | 1.2 |
| Dy | 4.8 | 5.9 | 10 | 16 | 28 | 16 | 21 | 16 | 8.3 | 6.8 |
| Ho | 0.91 | 1.2 | 2.2 | 3.2 | 5.5 | 3.2 | 4.6 | 3.3 | 1.6 | 1.3 |
| Er | 2.5 | 3.4 | 6.0 | 8.9 | 14 | 8.9 | 14 | 8.8 | 4.6 | 3.6 |
| Tm | 0.34 | 0.50 | 0.86 | 1.3 | 2.0 | 1.3 | 2.0 | 1.3 | 0.76 | 0.52 |
| Yb | 2.1 | 3.4 | 5.9 | 9.6 | 13 | 9.6 | 15 | 8.2 | 4.9 | 3.2 |
| Lu | 0.28 | 0.50 | 0.82 | 1.3 | 1.8 | 1.4 | 2.2 | 1.2 | 0.70 | 0.44 |
| Hf | 7.2 | 4.5 | 14 | 15 | 42 | 10 | 22 | 48 | 30 | 12 |
| Ta | 2.9 | 1.3 | 7.8 | 2.6 | 15 | 2.5 | 4.7 | 14 | 4.0 | 3.9 |
| Pb | 39 | 6.7 | 15 | 16 | 34 | 171 | 19 | 31 | 49 | 31 |
| Th | 10 | 4.3 | 22 | 12 | 49 | 10 | 16 | 60 | 44 | 16 |
| U | 6.7 | 5.8 | 4.4 | 5.7 | 11 | 5.1 | 7.1 | 20 | 21 | 20 |

<dl, below detection limit.

Table 4 Major-element oxides (%) and trace element concentrations (μg/g) of the coal and noncoal samples from the Jinqi underground coal mine (on whole-coal basis).

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | JQ-01 | JQ-02 | JQ-03 | JQ-04 | JQ-05 | JQ-06 | JQ-07 | JQ-F1 | JQ-F2 | JQ-F3 |
| SiO2 | 11 | 14 | 13 | 29 | 3.5 | 13 | 10 | 40 | 48 | 50 |
| TiO2 | 0.43 | 0.20 | 0.31 | 0.86 | 0.33 | 0.43 | 0.40 | 1.6 | 3.1 | 2.9 |
| Al2O3 | 5.1 | 3.3 | 6.4 | 17 | 3.9 | 5.0 | 5.0 | 31 | 31 | 29 |
| Fe2O3 | 13 | 3.2 | 0.74 | 0.69 | 0.61 | 1.2 | 0.96 | 1.1 | 2.3 | 2.0 |
| MgO | 0.21 | 0.06 | 0.12 | 0.31 | 0.06 | 0.17 | 0.19 | 0.20 | 0.17 | 0.32 |
| CaO | 0.12 | 0.08 | 0.10 | 0.17 | 0.13 | 0.10 | 0.12 | 0.28 | 0.27 | 0.31 |
| Na2O | 0.02 | 0.01 | 0.02 | 0.09 | 0.01 | 0.02 | 0.02 | 0.01 | 0.14 | 0.01 |
| K2O | 0.52 | 0.11 | 0.29 | 0.72 | 0.11 | 0.41 | 0.46 | 0.49 | 0.26 | 0.78 |
| Li | 44 | 38 | 59 | 111 | 42 | 71 | 75 | 271 | 301 | 337 |
| Be | 3.7 | 5.9 | 11 | 5.1 | 13 | 8.7 | 11 | 8.6 | 8.0 | 7.6 |
| P | 81 | 127 | 158 | 108 | 165 | 182 | 265 | 260 | 210 | 320 |
| Sc | 1.8 | <dl | 1.5 | 1.3 | 2.0 | 0.9 | 3.7 | 19 | 32 | 29 |
| V | 264 | 46 | 33 | 31 | 33 | 41 | 162 | 105 | 264 | 398 |
| Cr | 81 | 20 | 20 | 14 | 21 | 25 | 37 | 141 | 333 | 586 |
| Mn | 153 | 25 | 15 | 21 | 4.4 | 8.5 | 9.1 | 8.3 | 7.5 | 10 |
| Co | 11 | 4.2 | 6.3 | 9.0 | 6.5 | 5.3 | 4.4 | 11 | 14 | 15 |
| Ni | 31 | 20 | 12 | 24 | 5.4 | 13 | 26 | 135 | 182 | 154 |
| Cu | 25 | 9.5 | 12 | 20 | 15 | 16 | 35 | 45 | 69 | 53 |
| Zn | 35 | 37 | 97 | 278 | 264 | 100 | 131 | 195 | 107 | 40 |
| Ga | 9.5 | 8.2 | 17 | 30 | 14 | 20 | 26 | 69 | 60 | 49 |
| Ge | 2.5 | 3.0 | 5.6 | 3.4 | 5.6 | 8.2 | 7.6 | 2.4 | 3.0 | 1.5 |
| As | 28 | 7.5 | 5.4 | 7.9 | 3.4 | 5.9 | 4.4 | 5.1 | 7.3 | 6.8 |
| Se | 32 | 13 | 15 | 12 | 7.8 | 13 | 13 | 10 | 12 | 11 |
| Rb | 10 | 2.1 | 6.8 | 12 | 2.1 | 9.3 | 13 | 8.6 | 4.9 | 15 |
| Sr | 104 | 76 | 47 | 31 | 72 | 44 | 66 | 47 | 49 | 76 |
| Y | 21 | 30 | 64 | 60 | 71 | 116 | 354 | 98 | 91 | 123 |
| Zr | 170 | 243 | 703 | 673 | 360 | 828 | 3010 | 1431 | 1472 | 890 |
| Nb | 22 | 29 | 69 | 194 | 37 | 103 | 110 | 165 | 94 | 63 |
| Mo | 109 | 15 | 3.6 | 1.8 | 3.3 | 3.3 | 5.5 | 5.1 | 1.4 | 1.8 |
| Sn | 3.7 | 1.6 | 4.2 | 7.1 | 4.2 | 7.3 | 21 | 15 | 8.5 | 5.2 |
| Cs | <dl | <dl | 1.1 | 2.2 | <dl | 2.5 | 3.5 | 2.2 | 1.5 | 3.3 |
| Ba | 21 | 5.8 | 27 | 15 | 6.6 | 17 | 23 | 15 | 95 | 22 |
| La | 41 | 56 | 114 | 61 | 144 | 155 | 206 | 66 | 49 | 141 |
| Ce | 70 | 129 | 267 | 142 | 295 | 270 | 375 | 130 | 69 | 201 |
| Pr | 7.8 | 12 | 23 | 13 | 27 | 29 | 45 | 15 | 8.2 | 23 |
| Nd | 27 | 43 | 83 | 44 | 99 | 103 | 161 | 55 | 31 | 79 |
| Sm | 5.1 | 9.2 | 18 | 9 | 19 | 21 | 38 | 14 | 10 | 14 |
| Eu | 0.40 | 0.81 | 1.3 | 0.71 | 1.4 | 1.6 | 3.5 | 1.8 | 2.5 | 2.7 |
| Gd | 4.3 | 7.7 | 15 | 8.3 | 17 | 19 | 41 | 15 | 13 | 15 |
| Tb | <dl | 1.0 | 2.0 | 1.3 | 2.2 | 2.7 | 7.5 | 3.0 | 2.3 | 3.1 |
| Dy | 3.8 | 6.4 | 12 | 9.2 | 13 | 19 | 58 | 19 | 14 | 21 |
| Ho | <dl | 1.2 | 2.4 | 1.9 | 2.5 | 3.8 | 12 | 3.8 | 2.9 | 4.5 |
| Er | 2.1 | 3.2 | 6.3 | 5.1 | 6.7 | 11 | 34 | 10 | 8.4 | 13 |
| Tm | <dl | 0.46 | 0.87 | 0.68 | 0.97 | 1.5 | 5.0 | 1.5 | 1.4 | 1.9 |
| Yb | 2.2 | 3.1 | 5.9 | 4.4 | 6.7 | 9.6 | 33 | 11 | 9.7 | 13 |
| Lu | <dl | 0.42 | 0.81 | 0.64 | 0.98 | 1.3 | 4.6 | 1.4 | 1.4 | 1.8 |
| Hf | 4.3 | 6.4 | 16 | 23 | 7.6 | 20 | 40 | 40 | 35 | 21 |
| Ta | 1.5 | 2.5 | 4.3 | 19 | 2.0 | 3.6 | 2.2 | 5.9 | 6.0 | 4.4 |
| Pb | 30 | 14 | 10 | 13 | 8.6 | 45 | 15 | 37 | 24 | 24 |
| Th | 5.5 | 12 | 17 | 45 | 7.0 | 19 | 12 | 53 | 48 | 25 |
| U | 47 | 10 | 4.7 | 6.7 | 3.5 | 7.3 | 18 | 22 | 17 | 11 |

<dl, below detection limit.