**Supplementary documents**

Supp. Figure 1. Chondrite-normalized REE spectra of magnetite-grunerite-hedenbergite of silicate facies iron formation (a) and microclinized biotite gneisses III (b) of the Olenegorsk deposit, as well as of zircons from these rocks (c and d, respectively) (Ivanyuk *et al.* 2017). REE spectra of oceanic basalts are provided for comparison (Ivanyuk *et al.* 2017).



Supp. Table 1. Summarized U-Pb (zr, bd) isotope data on the Olenegorsk, Kirovogorsk and Eastern Bolshaya Litsa BIF bands.

|  |  |  |  |
| --- | --- | --- | --- |
| **Petrography** | **Locality** | **U-Pb (zr, bd) age, Ma** |  |
| Amphibolites | Eastern Bolshaya Litsa BIF | 2813±48 |
| Tonalite, country rocks | Pecheguba | 2790±7 |
| Muscovite gneisses, country rocks | Kirovogorsk deposit | 2760±7 |
| Rhyolite, intra-ore rhyolite | Komsomolsk BIF | 2750±24 |
| *Kirovogorsk BIF* |
| BIF | Kirovogorsk deposit | 2780±13 |
| Cutting dolerite dykes | Kirovogorsk deposit | 2740±112738±6 |
| Zeolitized intra-ore granite pegmatite | Kirovogorsk deposit | 2650-2644 |
| *Olenegorsk BIF* |
| Scapolite-quartz-plagioclase segregation in hornblendite gneisses | Olenegorsk deposit | 2670-2570 |
| Intra-ore feldspar-rich pegmatites | Olenegorsk deposit | 2750±15 |

Supp. Table 2. Isotope Sm-Nd and initial (ISr) data on main rocks from BIFs of the Olenegorsk area.

See description of the Rb-Sr method in (Bayanova *et al.* 2009).

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Name** | **Petrology** | **Sm,****ppm** | **Nd,****ppm** | **147Sm/144Nd** | **143Nd/144Nd****±2σ** | **εNd****(2.7 Ga)** | **TDM** | **ISr** | **±2σ** |
| MSK-72/1 | BIF | 4.67 | 15.28 | 0.1546 | 0.512338±7 | +1.76 | 3154 | 0.7074 | ±9 |
| MSK-72/2 | Qtz-Fsp | 0.68 | 2.82 | 0.1455 | 0.512034±10 | +1.25 | 2988 | 0.7083 | ±8 |
| MSK-72/3 | Amphibolite | 3.45 | 12.31 | 0.1592 | 0.512297±9 | +2.82 | 2917 | 0.7039 | ±11 |
| MSK-72/4 | Gar-Bt-gneisses | 0.87 | 4.65 | 0.1130 | 0.511447±21 | +2.21 | 2670 | 0.7075 | ±12 |
| MSK-72/5 | Dolerite dyke | 4.07 | 19.27 | 0.1278 | 0.511559±10 | +2.83 | 2811 | 0.7031 | ±9 |
| MSK-72/6 | Metasomatite | 0.39 | 1.84 | 0.1276 | 0.511636±10 | -0.70 | 2772 | 0.7091 | ±13 |
| MSK-72/7 | Gabbro-norite dyke | 1.69 | 7.64 | 0.1335 | 0.511498±17 | -0.38 | 3125 | 0.7037 | ±9 |
| MSK-73/1 | Gar-Bt-gneisses | 2.33 | 12.65 | 0.1115 | 0.511267±9 | +2.78 | 2797 | 0.7196 | ±6 |
| MSK-74/1 | Bt-gneisses | 2.67 | 14.91 | 0.1082 | 0.511080±17 | +0.27 | 2976 | 0.7099 | ±8 |
| MSK-75/1 | Bt-gneisses | 2.30 | 11.32 | 0.1230 | 0.511294±13 | -0.71 | 3103 | 0.7101 | ±11 |

Supp. Table 3. Isotope U-Pb data on different types of zircon from rocks of the Olenegorsk and Kirovogorsk BIFs.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Type** | **Weight, mg** | **Content,****ppm** | **Isotope ratio \*** | **Age, Ma\*\*** | **Rho\*\*\*** |
| Pb | U | 206Pb204Pb | 206Pb207Pb | 206Pb208Pb | 207 Pb235 U | 206 Pb238 U | 207 Pb206 Pb |
| *Magnetite-grunerite-hedenbergite of silicate facies iron formation, Olenegorsk deposit* |
| I-1 | 0.40 | 185.2 | 364.1 | 2458 | 5.3944 | 29.151 | 11.9918 | 0.482109 | 2657 | 0.97 |
| I-2 | 0.40 | 102.6 | 197.5 | 1464 | 5.2532 | 15.330 | 11.8312 | 0.475811 | 2666 | 0.96 |
| I-3 | 0.50 | 190.9 | 369.6 | 3869 | 5.4477 | 42.554 | 12.3343 | 0.495869 | 2657 | 0.91 |
| *Microclinized biotite gneisses III, Olenegorsk deposit (metamorphic zircon)* |
| III-1 | 0.55 | 313.2 | 629.1 | 44369 | 5.4354 | 50.846 | 12.1811 | 0.480908 | 2687 | 0.96 |
| III-2 | 0.25 | 130.3 | 262.0 | 6493 | 5.4076 | 27.037 | 11.9160 | 0.472138 | 2681 | 0.96 |
| III-3 | 0.60 | 315.1 | 634.5 | 6451 | 5.4213 | 16.940 | 11.6639 | 0.463350 | 2676 | 0.96 |
| *Nodular muscovite gneisses V, Kirovogorsk deposit (magmatic zircon)* |
| V-1 | 0.25 | 10.3 | 16.13 | 398 | 4.4575 | 4.6711 | 13.3578 | 0.494999 | 2779 | 0.95 |
| V-2 | 0.40 | 69.0 | 128.0 | 6451 | 5.1971 | 9.9926 | 12.8671 | 0.484033 | 2747 | 0.97 |
| V-3 | 0.40 | 84.5 | 158.1 | 5152 | 5.1696 | 9.6920 | 12.6949 | 0.477997 | 2752 | 0.92 |

\*All ratios are corrected for blanks of 0.08 ng for Pb and 0.04 ng for U and for mass discrimination of 0.12±0.05%.

\*\*Correction for common Pb was determined for the age according to Stacey and Kramers (1975).

\*\*\*Correlation between 206Pb/238U vs. 207Pb/235U axis.

Supp. Table 4. SHRIMP-II isotope data on single zircon grains from rocks of the Olenegorsk BIF.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Zone** | **Weight,****Mg** | **Content,****ppm** | **Isotope ratio\*** | **Age, Ma\*\*** | **Discordance, %** |
| **Pb** | **U** | **206Pb/204Pb** | **206Pb/238U****±2σ** | **207Pb/235U****±2σ** | **207Pb/206Pb****±2σ** | **206Pb/ 238U****±2σ** | **207Pb/235U****±2σ** | **207Pb/206Pb****±2σ** |
| *Magnetite-grunerite-hedenbergite of silicate facies iron formation, Olenegorsk deposit* |
| 1 | 0.04 | 126.95 | 237.24 | 18261 | 0.5095±0.0010 | 12.805±0.026 | 0.18141±0.00010 | 2655±5 | 2661±5 | 2665.8±2 | 0.4 |
| 2 | 0.04 | 122.88 | 232.77 | 7614.7 | 0.5035±0.0010 | 12.634±0.027 | 0.18170±0.00011 | 2629±5 | 2651±6 | 2668.5±2 | 1.5 |
| 3 | 0.06 | 154.48 | 280.96 | 2211.3 | 0.5019±0.0008 | 12.607±0.022 | 0.18145±0.00009 | 2622±4 | 2647±6 | 2666.2±1 | 1.7 |
| 4 | 0.05 | 190.94 | 369.62 | 3869.4 | 0.4959±0.0008 | 12.434±0.021 | 0.18040±0.00008 | 2596±4 | 2630±4 | 2656.6±1 | 2.3 |
| *Microclinized biotite gneisses III, Olenegorsk deposit* |
| 1 | 0.06 | 22.457 | 82.931 | 929.98 | 0.4629±0.0037 | 11.212±0.111 | 0.11342±0.00067 | 1504±12 | 1657±16 | 2455±14 | 38.7 |
| 2 | 0.03 | 33.722 | 62.98 | 1777.4 | 0.4977±0.0030 | 12.526±0.077 | 0.18251±0.00027 | 2604±16 | 2645±16 | 2675±4 | 2.7 |
| 3 | 0.03 | 33.722 | 61.706 | 1979.4 | 0.5080±0.0031 | 12.885±0.081 | 0.18251±0.00027 | 2648±16 | 2664±17 | 2686±4 | 1.4 |

\*All ratios are corrected for blanks of 1 pg for Pb and 10 pg for U and for mass discrimination of 0.12 ± 0.05%.

\*\*Correction for common Pb was determined for the age according to Stacey and Kramers (1975).

Supp. Table 5. SHRIMP data on metamorphic zircons from metasomatic rocks of the Olenegorsk and Kirovogorsk BIFs.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Probe** | **206Pbc, %** | **U,****ppm** | **Th, ppm** | **232Th/ 238U** | **206Pb\*, ppm** | **Age, Ma 206Pb/****238U** | **Age, Ma****207Pb/****206Pb** | **Dis. %** | **Total****238U/206Pb****±%** | **Total****207Pb/206Pb****±%** | **238U/206Pb\*****±%** | **207Pb\*/206Pb\*****±%** | **207Pb\*/235U****±%** | **206Pb\*/238U****±%** | **Err.****corr.** |
| *Quartz-epidote-andradite-diopside of silicate facies iron formation, Olenegorsk deposit* |
| II-1-1 | – | 138 | 83 | 0.62 | 64.9 | 2816±34 | 2778.2±9.8 | -1 | 1.826±1.5 | 0.1941±0.6 | 1.826±1.5 | 0.1942±0.6 | 14.67±1.6 | 0.5478±1.5 | 0.93 |
| II-1-2 | 0.00 | 5 | 2 | 0.32 | 2.03 | 2440±88 | 2664±70 | 9 | 2.174±4.3 | 0.1812±4.2 | 2.174±4.3 | 0.1812±4.2 | 11.49±6 | 0.46±4.3 | 0.71 |
| II-2-1 | 0.01 | 168 | 149 | 0.92 | 76.1 | 2734±34 | 2783.8±9.3 | 2 | 1.893±1.5 | 0.1950±0.56 | 1.893±1.5 | 0.1949±0.57 | 14.2±1.6 | 0.5283±1.5 | 0.94 |
| II-2-2 | 0.06 | 678 | 21 | 0.03 | 301 | 2684±31 | 2646±7.9 | -1 | 1.935±1.4 | 0.17976±0.46 | 1.936±1.4 | 0.17926±0.47 | 12.76±1.5 | 0.5164±1.4 | 0.95 |
| II-3-1 | 0.01 | 238 | 145 | 0.63 | 118 | 2942±34 | 2761.7±7.9 | -6 | 1.729±1.4 | 0.19237±0.48 | 1.729±1.4 | 0.19228±0.48 | 15.33±1.5 | 0.5782±1.4 | 0.95 |
| II-3-2 | 0.00 | 20 | 0 | 0.01 | 9.23 | 2807±49 | 2641±27 | -6 | 1.832±2.1 | 0.1787±1.6 | 1.832±2.1 | 0.1787±1.6 | 13.44±2.7 | 0.546±2.1 | 0.80 |
| II-3-3 | 0.00 | 17 | 0 | 0.02 | 8.09 | 2845±51 | 2654±29 | -7 | 1.802±2.2 | 0.1801±1.7 | 1.802±2.2 | 0.1801±1.7 | 13.78±2.8 | 0.555±2.2 | 0.79 |
| II-4-1 | 0.00 | 288 | 255 | 0.92 | 146 | 2998±36 | 2788.4±7.3 | -7 | 1.689±1.5 | 0.19544±0.45 | 1.689±1.5 | 0.19544±0.45 | 15.96±1.6 | 0.5922±1.5 | 0.96 |
| II-4-2 | 0.03 | 508 | 14 | 0.03 | 222 | 2652±30 | 2642.7±6.3 | 0 | 1.965±1.4 | 0.17915±0.38 | 1.965±1.4 | 0.1789±0.38 | 12.55±1.5 | 0.5089±1.4 | 0.97 |
| II-5 | 0.03 | 142 | 62 | 0.46 | 65.5 | 2777±36 | 2786±11 | 0 | 1.857±1.6 | 0.1954±0.67 | 1.857±1.6 | 0.1952±0.68 | 14.49±1.7 | 0.5385±1.6 | 0.92 |
| II-6 | 0.04 | 134 | 69 | 0.53 | 61.6 | 2766±36 | 2777±15 | 0 | 1.865±1.6 | 0.1945±0.91 | 1.866±1.6 | 0.1941±0.92 | 14.34±1.8 | 0.5359±1.6 | 0.87 |
| *Magnetite-calcite-dolomite rock IV, Kirovogorsk deposit* |
| IV-1-1 | 0.05 | 258 | 151 | 0.60 | 117.0 | 2738±32 | 2655±12 | -3 | 1.889±1.4 | 0.1806±0.71 | 1.890±1.4 | 0.1802±0.73 | 13.15±1.6 | 0.5291±1.4 | 0.89 |
| IV-1-2 | 0.03 | 224 | 115 | 0.53 | 91.9 | 2515±31 | 2646.1±8.3 | 5 | 2.095±1.5 | 0.17954±0.49 | 2.096±1.5 | 0.17927±0.5 | 11.80±1.6 | 0.4772±1.5 | 0.95 |
| IV-2-1 | 0.00 | 236 | 96 | 0.42 | 103.0 | 2643±31 | 2652.4±7.9 | 0 | 1.973±1.4 | 0.17995±0.48 | 1.973±1.4 | 0.17995±0.48 | 12.57±1.5 | 0.5068±1.4 | 0.95 |
| IV-2-2 | 0.00 | 186 | 58 | 0.32 | 88.8 | 2844±34 | 2651.2±9.2 | -7 | 1.803±1.5 | 0.17982±0.55 | 1.803±1.5 | 0.17982±0.55 | 13.75±1.6 | 0.5546±1.5 | 0.94 |
| IV-3 | 0.14 | 196 | 76 | 0.40 | 88.0 | 2711±32 | 2645.8±9.7 | -2 | 1.910±1.4 | 0.18046±0.53 | 1.912±1.4 | 0.1792±0.59 | 12.92±1.6 | 0.5229±1.4 | 0.93 |
| IV-4 | 0.15 | 190 | 81 | 0.44 | 82.9 | 2647±34 | 2645±10 | 0 | 1.966±1.5 | 0.18052±0.55 | 1.969±1.5 | 0.1792±0.61 | 12.54±1.7 | 0.5078±1.5 | 0.93 |
| IV-5 | – | 241 | 93 | 0.40 | 109.0 | 2722±33 | 2655.1±8.2 | -2 | 1.904±1.5 | 0.1802±0.49 | 1.903±1.5 | 0.18024±0.49 | 13.06±1.6 | 0.5254±1.5 | 0.95 |
| IV-6 | 0.03 | 240 | 77 | 0.33 | 106.0 | 2670±32 | 2649.1±8.7 | -1 | 1.948±1.4 | 0.17988±0.5 | 1.949±1.4 | 0.17959±0.52 | 12.71±1.5 | 0.5131±1.4 | 0.94 |

All errors are corrected for 1 σ level; Pbc and Pb\* are portions of common and radiogenic Pb; standards

Supp.Table 6. REE content in zircon and country rocks of the Bauman quarry of the Olenegorsk BIF (ppm).

|  |  |  |
| --- | --- | --- |
| **Element** | **Magnetite-grunerite-hedenbergitre of silicate facies iron formation** | **Microclinized biotite gneisses III** |
| **Zircon** | **Rock** | **Zircon** | **Rock** |
| **Core** | **Rim** | **Core** | **Rim** |
| La | 0.42 | 1.42 | 7.38 | 4.58 | 1.18 | 16.27 |
| Ce | 2.81 | 17.5 | 14.94 | 22.2 | 18.8 | 36.46 |
| Pr | 0.12 | 0.60 | 1.73 | 1.44 | 3.19 | 4.48 |
| Nd | 0.79 | 4.22 | 6.17 | 5.78 | 19.1 | 17.38 |
| Sm | 0.62 | 3.95 | 1.27 | 1.32 | 5.40 | 3.53 |
| Eu | 0.30 | 0.77 | 0.50 | 9.35 | 4.15 | 1.10 |
| Gd | 1.97 | 18 | 1.16 | 10.2 | 10.3 | 2.45 |
| Tb | – | – | 0.16 | – | – | 0.36 |
| Dy | 4.37 | 80.3 | 0.83 | 93.8 | 66.9 | 1.50 |
| Ho | – | – | 0.17 | – | – | 0.27 |
| Er | 4.44 | 199.4 | 0.49 | 348 | 277 | 0.74 |
| Tm | – | – | 0.08 | – | – | 0.09 |
| Yb | 5.78 | 405.6 | 0.50 | 1140 | 955 | 0.59 |
| Lu | 0.83 | 69.4 | 0.07 | 176 | 156 | 0.08 |
|  |  |  |  |  |  |  |