Pyrrhotite–silicate melt partitioning of rhenium and the deep rhenium cycle in subduction zones

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1. Pyrite is a major host for Re in reduced sediments

Fig. 1B in the main text shows that the Re concentration and TOC are correlated in reduced sediments. However, this does not mean that in reduced sediments, Re is mainly hosted within organic compounds or graphite. During weathering of Earth's surface rocks, Re-rich sulfides are readily oxidized to form water-soluble ReO_4^- and SO_4^{2-} , which are then transported to oceans. Through reduction by organic compounds in anoxic sediments, SO_4^{2-} is reduced to H_2S , HS^- and S^{2-} species in seawater (Vairavamurthy et al., 1995). Studies found that ReO_4^- is not stable in sulfidic seawater and readily precipitates and forms ReS_2 or Re polysulfides (e.g., Re_2S_7 ; Xiong, 2002; Dolor, 2005). Therefore, the Re concentration and TOC are correlated in reduced sediments. Many previous studies have documented that both Re and Mo, and PGE as well, are mainly stored in pyrite in organic-rich sediments (Brumsack, 2006; Colodner, 1991; Gadd et al., 2019; Pašava et al., 2019; Rosenthal et al., 1995; Sundby et al., 2004; Wanty and Goldhaber, 1992; Zheng et al., 2000). For example, Gadd et al. (2019) analyzed sulfide minerals in reduced sediments and the bulk sediments, using LA-ICP-MS, and found that the Re concentration in pyrite is as high as 500 ppm. The authors concluded that pyrite is the principal host of Re in reduced sediments. Fig. S1 shows a strong correlation between the Re and S concentration in reduced sediments, which also supports that Re is mainly tied to sulfides in reduced sediments. In addition, we have also analyzed the graphite in contact with pyrrhotite in this study, using LA-ICP-MS, the results of which show that negligible Re is stored/dissolved in graphite (Fig. S3E). Therefore, graphite cannot play a considerable role in controlling the Re budget in graphite-saturated, subducting slabs.

2. The proportion of reduced sediments in modern marine sediments

To estimate the proportion of reduced sediments in total subducted marine sediments, we assume that organic carbon exists mainly in reduced sediments and non-organic carbon is present mainly as carbonates (100% CaCO_3). The organic carbon to non-organic carbon ratio is ~ 0.2 in trench sediments (Clift, 2017). Plank and Langmuir (1998) suggested that a global subducting sediment (GLOSS) may contain ~ 7 wt.%

carbonates, which suggests that GLOSS may contain ~ 0.84 wt. % non-organic carbon. Therefore, organic carbon is about ~ 0.17 wt. % in subducted sediments. The reduced sediments averagely contain ~ 2 wt. % organic carbon (Sheen et al., 2018). Accordingly, GLOSS may on average contain ~ 9 wt.% reduced sediments.

3. Experimental methods

3.1. Starting materials

Starting materials included a synthetic silicate, anhydrite (CaSO_4), pyrrhotite (FeS), graphite, and pure water. The synthetic silicate compositions are representative of average, low-degree experimental partial melts of subducted pelitic sediments at 0.5–5 GPa and 600–1100 °C (PMSC, Table S1) (Duncan and Dasgupta, 2014). The silicate was prepared from reagent grade oxides SiO_2 , TiO_2 , Al_2O_3 , MgO , FeO , MnO , P_2O_5 , K_2O , Na_2O and carbonates CaCO_3 , Na_2CO_3 , and K_2CO_3 . SiO_2 , TiO_2 , Al_2O_3 , and MgO powder were each heated over night at 1000 °C, CaCO_3 at 200 °C, and Na_2CO_3 and K_2CO_3 at 110 °C to minimize adsorbed water contents. The chemical powder of SiO_2 , TiO_2 , Al_2O_3 , MgO , Na_2CO_3 and K_2CO_3 were mixed and ground in acetone for ~ 1 h, and then dried at room temperature. The dried mixture was then heated in a muffle furnace at 1000 °C overnight for decarbonation. The mixture was subsequently mixed with FeO , MnO and P_2O_5 and ground in acetone for another 1 h, dried at room temperature, and stored in a vacuumed oven at 100 °C. The major element contents of the silicate were consistent with the target contents within error, as confirmed by electron microprobe analysis of a silicate glass synthesized at 1600 °C (Table S1). About 1000 ppm metallic Re was mixed with the pyrrhotite powder, which was then sintered in a graphite capsule at 1100 °C and 1 GPa for 8 h. For each experiment, ~ 30 mg of the starting materials, including ~ 63 – 67 wt.% silicate powder, ~ 30 wt.% pyrrhotite powder, and ~ 3 – 7 wt.% water, were packed into Au capsules, which were welded shut using a LAMPERT PUK-U3 welding machine and checked by drying and weighing to ensure no water leakage.

3.2. High-pressure experiments

Experiments were performed at 950–1080 °C and 1–3 GPa in an end-loaded piston

cylinder apparatus (Max Voggenreiter LPC250). The used assembly is composed of graphite furnace + Pyrex glass + talc sleeve + MgO spacers. Sample capsule was positioned at the center of the graphite furnace. The thermocouple wires were loaded in a four-bore alumina sleeve, with the junction in contact with an alumina disk (0.5 mm thickness) at the top of the sample capsule. Experiments at 2–3 GPa were performed using a 1/2-inch assembly and those at 1 GPa were conducted using a 3/4-inch assembly. Pressure of the experiments was estimated from the hydraulic pressure that was calibrated against the quartz-coesite and kyanite-sillimanite transitions, with a 20% friction correction applied for the 1/2-inch assembly and an 18% friction correction applied for the 3/4-inch assembly. The pressure uncertainty was estimated to be better than 0.1 GPa. Temperature of the experiments was monitored by S-type (Pt-Pt₉₀Rh₁₀) thermocouples with an estimated temperature uncertainty of ± 10 °C. The experiments were first pressurized to the desired pressures and then automatically heated to the desired temperatures at a rate of 50 °C/min. The experimental durations ranged from 72 to 90 h. All experiments were terminated by turning off electric power to the graphite heaters. The recovered capsules were sectioned, mounted in epoxy resin, and polished for optical observations and subsequent EPMA and LA-ICP-MS analyses.

Experimental oxygen fugacity (f_{O_2}) was controlled using both a double-capsule technique and an inner buffer technique. For the double-capsule technique, the capsule assembly consists of an outer platinum (Pt₉₅Rh₀₅) capsule (5 mm O.D., 4.5 mm I.D.) and a cylindrical inner Au sample capsule (3 mm O.D., 2.8 mm I.D.). External f_{O_2} buffers corresponding to the Ni–NiO and Re–ReO₂ equilibria (Pownceby and O'Neill, 1994; Taylor et al., 1992) were applied using a method similar to that as described by Jakobsson (2012). In this technique, ~2 mg of H₂O and ~10 mg of buffer material were loaded at the bottom of the outer Pt₉₅Rh₀₅ capsule. To prevent the contact of the inner Au capsule from the buffer material, which can cause melting of the inner Au capsule, a Pt disc was used to separate the inner Au capsule from the buffer material. The intactness of the buffer material (Ni–NiO and Re–ReO₂) was confirmed by using X-ray energy spectrum analysis (EDS) of electron microprobe. In the inner buffer technique, in addition to the starting material mentioned above, ~10 wt.% anhydrite or graphite

was loaded into the Au capsules.

3.3. Oxygen fugacity and sulfur fugacity calculations

Experimental oxygen fugacity ($f\text{O}_2$) was controlled using both a double-capsule technique and an inner buffer technique. For the double-capsule technique, the oxygen fugacity ($f\text{O}_2$) of inner capsule can be written as follows (Jakobsson et al., 2014):

$$\log f\text{O}_2 (\text{inner capsule}) = \log f\text{O}_2 (\text{buffer}) + 2\log(a\text{H}_2\text{O})$$

The actual sample $f\text{O}_2$ of inner capsule is subject to the water activity of the silicate melt. The H_2O activities were estimated based on the model of Burnham (1979) as done previously (Botcharnikov et al., 2011; Jakobsson, 2014; Jégo and Dasgupta, 2014). The absolute $f\text{O}_2$ of the Re–ReO buffer (RRO) at the experimental P – T conditions was calculated using the calibration of Pownceby and O’Neil (1994), and the absolute $f\text{O}_2$ of the fayalite–magnetite–quartz (FMQ) and Ni–NiO (NNO) buffers was calculated using the calibrations of Frost (1991). For the inner buffer technique, the experimental $f\text{O}_2$ at graphite-saturation approximately equals the C–CO₂ (CCO) buffer because of the dissolution of significant amounts of CO₂ in the silicate melt (Duncan and Dasgupta, 2017), which is ~ 0.4 – 1.3 log units below the FMQ buffer at 1–3 GPa (Jakobsson and Oskarsson, 1994). The sulfide and anhydrite (referring to as the SSO buffer) stably coexist in rhyodacitic to rhyolitic melts over a narrow $f\text{O}_2$ range at 1–3 GPa (FMQ+1.5 to FMQ+2.0; Jégo and Dasgupta, 2014; Li et al., 2019). Overall, the experimental $f\text{O}_2$ in this study covers a range over $\sim \text{FMQ}-1.3$ to $\sim \text{FMQ}+2$ (Table S2).

Sample sulfur fugacity ($\log f\text{S}_2$) was calculated based on the major element compositions of Po crystals, using an experimental calibration of Toulmin and Barton (1964):

$$N_{\text{FeS}} = \text{FeS} / (\text{FeS} + \text{S}_2) \quad (1)$$

$$\log f\text{S}_2 = (70.0 - 85.83 N_{\text{FeS}}) \times (1000/T - 1) + 39.30 \sqrt{(1 - 0.9981 N_{\text{FeS}})} - 11.91 \quad (2)$$

in which N_{FeS} is the mole fraction of FeS in the FeS–S₂ system, and T is the temperature in K. The calculated sample $\log f\text{S}_2$ ranged from -1.8 to 1.4 (Table S2), which is positively correlated with $\log f\text{O}_2$ (ΔFMQ) (Fig. S4), as observed in previous studies (Botcharnikov et al., 2011; Li and Audétat, 2012). Such covariation of $f\text{O}_2$ and $f\text{S}_2$ can

be explained by a reaction $\text{FeO (silicate melt)} + 1/2\text{S}_2 \text{ (gas)} = \text{FeS (sulfide)} + 1/2\text{O}_2 \text{ (gas)}$, because this reaction implies that in a $f\text{S}_2$ -unbuffered but sulfide-saturated experiment, $f\text{S}_2$ must increase with increasing $f\text{O}_2$.

4. Analytical methods

4.1. Electron probe microanalysis (EPMA)

Chemical analysis (EDS and WDS) and back-scattered electron (BSE) imaging of pyrrhotite, garnet and quenchable silicate melts were performed using an electron probe microanalyzer (EPMA) JEOL JXA-8230. The analytical conditions were 15 kV accelerating voltage, 20 nA beam current and 1 μm diameter beam size for garnets, and 10 nA beam current and 20 μm diameter beam size for the quenched silicate melts. Sulfides were analyzed with 20 kV acceleration voltage and 20 nA beam current and 10 μm diameter beam size. The peak counting time was 10 s for Na and K, 20 s for Si, Fe, Ca and Al, 40 s for Mg and Ti, and 60 s for Mn. Both natural and synthetic standards were used to calibrate the instrument. For sulfide analysis, Fe and S were calibrated on a synthetic pyrrhotite with well-known Fe: S ratio. For silicate melts, Na was calibrated on albite, K on orthoclase, Si and Ca on chrome-diopside, Ti and Mn on ilmenite, Si on enstatite, Mg on olivine, Al on spinel, P on GaP, Fe on magnetite. The S in reduced and oxidized glasses were calibrated on pyrrhotite and barite, respectively. Accelerating voltage of 15 kV, beam current of 70 nA and beam size of 20 μm were used, and the peak counting time was 60 s. Analytical accuracy is better than 2% relative for SiO_2 , Al_2O_3 , and CaO , 5% relative for TiO_2 , FeO , MnO , MgO , K_2O , and P_2O_5 , and 10% relative for Na_2O and S.

4.2. LA-ICP-MS

Major and trace elements of pyrrhotite, quenchable silicate melts, and silicate minerals (garnet) were analyzed by LA-ICP-MS. These analyses were carried out on an Agilent 7900 Quadrupole ICP-MS coupled to a Photon Machines Analyte HE 193 nm ArF Excimer Laser Ablation system (Ning et al., 2017). The laser was operated at

a frequency of 8 Hz and with a laser energy of $\sim 2 \text{ J/cm}^2$ for 40 s after measuring a gas blank for 20 s. The laser beam size was varied from 30 to 70 μm . Helium was applied as a carrier gas and was mixed with argon used as the make-up gas via a T-connector before entering the ICP. Dwell times were 10 ms for the isotopes ^{23}Na , ^{25}Mg , ^{27}Al , ^{29}Si , ^{39}K , ^{42}Ca , ^{49}Ti , ^{55}Mn , ^{57}Fe , ^{65}Cu , ^{98}Mo , ^{107}Ag , and 20 ms for ^{185}Re and ^{197}Au . NIST 610, NIST 612 and BCR-2G were used as external standards to plot calibration curves using preferred element concentrations for the USGS reference glasses from the GeoReM database (<http://georem.mpch-mainz.gwdg.de/>). Si and Fe determined by electron microprobe were used as internal standards for silicates and pyrrhotite, respectively. The off-line data processing was performed using a program called ICPMSDataCal (Liu et al., 2008). The analytical uncertainties for major and trace elements are $\sim 5\%$ and 10% , respectively.

5. Attainment of equilibrium partitioning

The experimental durations were 72 h for experiments at 1000–1080 $^{\circ}\text{C}$, 90 h for experiments at 950 $^{\circ}\text{C}$. Several lines of evidence suggest that equilibrium partitioning was approached in our experiments. First, both the quenched silicate melts and Po crystals are homogeneous in major and trace elements. No chemical gradient was found in the silicate melt as a function of distance to the Po crystals (Fig. S2A). Second, $D_{\text{Re}}^{\text{po/sm}}$ are strongly correlated with $f\text{O}_2$ (Fig. 3 in the main text), and $D_{\text{Re}}^{\text{po/sm}}$ can be fully described as a multi-function of P – T , $f\text{O}_2$, and melt FeO_{tot} content (Eq. 1 in the main text). Third, $D_{\text{Re}}^{\text{po/sm}}$ and $D_{\text{Mo}}^{\text{po/sm}}$ are strongly correlated (Table S2), as observed in previous high-temperature experiments (1100–1200 $^{\circ}\text{C}$) (Feng and Li, 2019). All these should not be observed if equilibrium partitioning of Re were not approached.

6. Parameters that affect Re partitioning between pyrrhotite and silicate melt

The partitioning of Re between pyrrhotite (Po) and silicate melt (sm) can be described as:

in which x and y refer to an average valence state of Re in Po and silicate melt, respectively. The equilibrium constant of this reaction can be written as:

$$K = \frac{aReO_{y/2} \cdot fS_2^{x/4}}{aReS_{x/2} \cdot fO_2^{y/4}} \quad (2)$$

which can be further arranged as:

$$\log K = \log aReO_{y/2} - \log aReS_{x/2} + x/4 \log fS_2 - y/4 \log fO_2 \quad (3)$$

$$\log \frac{aReS_{x/2}}{aReO_{y/2}} = x/4 \log fS_2 - y/4 \log fO_2 + \log K \quad (4)$$

$$\log D_{Re}^{po/sm} = x/4 \log fS_2 - y/4 \log fO_2 + \log K - \log \frac{\gamma^{MS}_{x/2}}{\gamma^{MO}_{y/2}} + C \quad (5)$$

in which $aReS_{x/2}$ and $aReO_{y/2}$ are the activity of $ReS_{x/2}$ and $ReO_{y/2}$ in Po and silicate melt, respectively; $\gamma^{ReS}_{x/2}$ and $\gamma^{ReO}_{y/2}$ are the activity coefficients of $ReS_{x/2}$ and $MO_{y/2}$ in Po and silicate melt, respectively; $D_{Re}^{po/sm}$ are the partition coefficients of Re between Po and silicate melt; C is a constant. Eq. (5) implies that $\log D_{Re}^{po/sm}$ should be a function of fS_2 , fO_2 , temperature, and compositions of Po and silicate melt. If Re has a same average valence state (n) in both Po and silicate melt, then Eq. (5) can be written as:

$$\log D_{Re}^{po/sm} = n/4(\log fS_2 - \log fO_2) + \log K - \log \frac{\gamma^{ReS}_{x/2}}{\gamma^{ReO}_{y/2}} + C \quad (6)$$

By assuming $aFeS=1$ in sulfide, at a given P - T condition, if γ^{FeO} in silicate melt does not change greatly as the variation of the silicate melt compositions, $-1/2(\log fS_2 - \log fO_2)$ is correlated with the FeO content in silicate melt (Kiseeva and Wood, 2013):

$$\log(XFeO) = -1/2(\log fS_2 - \log fO_2) + C \quad (7)$$

In this case, Eq. (6) can be written as a function of the FeO content in silicate melt:

$$\log D_{Re}^{po/sm} = -n/2 \log(XFeO) + \log K - \log \frac{\gamma^{ReS}_{x/2}}{\gamma^{ReO}_{y/2}} + C \quad (8)$$

If $\gamma^{ReS}_{x/2}$ and $\gamma^{ReO}_{y/2}$ do not vary greatly with the Po and silicate melt composition, respectively, Eq. (8) can be simplified as:

$$\log D_{Re}^{po/sm} = -n/2 \log(XFeO) + \log K + C \quad (9)$$

If temperature and pressure effects are considered, Eq. (9) can be further written as (Kiseeva and Wood, 2015; Li et al., 2021):

$$\log D_{Re}^{po/sm} = \frac{a}{T(K)} + b \cdot P(GPa)/T(K) - n/2 \log(XFeO) + C \quad (10)$$

where a and b are coefficients for the relevant terms. However, it should be noted that the valence state of Re in silicate melt and probably Po is a function of fO_2 ; at a given fO_2 , two or three valence states of Re (Re^{2+} , Re^{4+} , and Re^{6+}) could be present in the silicate melt and Po (Bennett and Brenan, 2013; Ertel et al., 2001; Holzheid et al., 1994). In this case, if Re^{2+} , Re^{4+} , and Re^{6+} partition differently between Po and silicate melt, then $\log D_{Re}^{po/sm}$ obtained at various fO_2 s depend not only on the FeO content in silicate melt but also on fO_2 . Li et al. (2021) found that the partition coefficients of Re, Mo, As, Sb, and Bi between different sulfide phases (sulfide liquid and monosulfide solid solution) and silicate melt, which elements have variable valence states, at various P - T - fO_2 can be empirically described as:

$$\log D^{sulfide/sm} = \frac{a}{T(K)} + b \cdot P(GPa)/T(K) - n/2 \log(XFeO) + c \cdot \Delta FMQ + C \quad (11)$$

Li and Audetat (2015), Feng and Li (2019), and Li et al. (2021) pointed that if an element M forms not only $M-O^{2-}$ but also $M-S^{2-}$ species in silicate melt, to what extent the $\log D_M^{sulfide/sm}$ is correlated with the FeO content in silicate melt depend significantly on the fraction of the element M that forms $M-O^{2-}$ species. Significant fractions of Pt, Pd, Au, Cu, Ag, and even Mn and W in silicate melt may form sulfide species, as discussed in recent studies (e.g., Zajacz et al., 2013; Bennett and Fei, 2018; Li et al., 2019; Evan et al., 2009; Laurenz et al., 2013).

By fitting our $D_{Re}^{po/sm}$ data into Eq. (11), we obtained the following equation to best describe $D_{Re}^{po/sm}$ in this study:

$$\log(D_{Re}^{po/sm}) = \frac{556(129) \cdot P(GPa)}{T(K)} - 0.87(0.26) \cdot \log(X_{FeO}, \text{wt.}\%) - 0.37(0.05) \cdot \Delta FMQ + 3.2(0.2) \quad (R^2=0.87) \quad (12)$$

Note that in Eq. (12) the $\frac{a}{T(K)}$ term is discarded because we found that the coefficient

a is insignificant statistically. In Eq. (12), $n/2$ equals 0.87, which corresponds to an average valence state of 1.74 for Re in silicate melt. This valence state is much lower than the usually suggested valence states of Re (4+ to 6+) in silicate (basaltic) melt at moderately reduced to oxidized conditions (FMQ-2 to FMQ+2) (Bennett and Brenan, 2013; Ertel et al., 2001; Holzheid et al., 1994; Mallmann and O'Neill, 2007). The most recent parameterizations of $D_{Re}^{sulfide/sm}$ and $D_{Mo}^{sulfide/sm}$ obtained at shallow mantle to crustal conditions (Li et al., 2021), including the Feng and Li (2019) data, yielded an average valence state of 1.76+ to 2.8+ for Mo and 2.6+ to 4+ for Re. These values are also lower than the suggested valences states of Mo and Re in basaltic melt at moderately reduced to oxidized conditions.

We acknowledge that at current stage, we cannot fully understand why the inferred average valence states of Re and Mo in silicate melt are lower than 4+ to 6+. However, the formation of Re-sulfide species in silicate melt may potentially resolve this issue. Brenan (2008) compared his experimentally measured $D_{Re}^{sulfide/sm}$ with those estimated based on Re solubility in sulfide and S-free silicate melt (Fonseca et al., 2007), and he found that the estimated $D_{Re}^{sulfide/sm}$ are considerably larger than the measured values. One explanation for the difference is that Re forms Re-sulfide species in the sulfide-saturated silicate melt (Brenan, 2008). However, if Re-sulfide species occur in S²⁻-bearing silicate melt, how the relative proportions of Re-sulfide vs. Re-oxide species change as a function of temperature, pressure, fO_2 , and silicate melt composition remains unknown, which needs systematical investigation in the future. In addition, we note that previous studies estimated the valence states of Re in basaltic melt at temperatures higher than 1200 °C, differing from the andesitic to granitic melts at 950–1080 °C in this study. Also, most experiments in previous studies were performed at 1 bar, but the experiments in this study were performed at 1–3 GPa. How the relative proportions of Re²⁺, Re⁴⁺, and Re⁶⁺ in silicate melt as a function of temperature, pressure, fO_2 , and silicate melt composition also remains to be studied. Our inferred average valence state of 1.74+ for Re in this study apparently implies a considerable fraction of Re occurring as Re²⁺ in the silicate melt, but again this needs future

confirmation. In light of all these uncertainties, we suggest an empirical equation such as Eq. (12) not to be used at conditions far beyond the calibration conditions.

7. Phase equilibrium modeling for sediment melting using Perple_X

The phase equilibria modeling for slab sediment melting was carried out using Perple_X (Connolly and Petrini, 2002) with the internal thermodynamic data set of Holland and Powell (2011) in the Na_2O – CaO – K_2O – FeO – MgO – Al_2O_3 – SiO_2 – H_2O – TiO_2 – O_2 (NCKFMASHTO) chemical system. MnO , P_2O_5 and Cr_2O_3 were ignored in the model system because they constitute only a small proportion of the bulk rock composition. The activity–composition (a–x) models for garnet (Grt), orthopyroxene (Opx), cordierite (Crd), biotite (Bt), chlorite (Chl), chloritoid (Ctd), staurolite (St), ilmenite (Ilm), and melt (Melt) were from White et al. (2014), clinopyroxene (Cpx) and clinoamphibole (Amph) from Green et al. (2016), plagioclase (Pl) and K–feldspar (Kfs) from Holland and Powell (2003), and spinel (Sp) from White et al. (2002). Quartz (Qz), coesite (Coe), lawsonite (Lws), Rutile (Rt), sphene (Spn), zoisite (Zo), and H_2O were considered as pure phases. We modeled the phase relations of slab sediments at 1.5–4 GPa and 500–1100 °C. Major element compositions of the used slab sediment (GLOSS) were taken from Plank and Langmuir (1998). The P – T phase relations were calculated with 4 wt. % H_2O , corresponding to water saturated melting (Hermann and Spandler, 2008; Hacker, 2008). Major elements and water were converted into molar percent of oxides, which were then used as an effective bulk rock composition. The $f\text{O}_2$ of the GLOSS sediment was varied by adding different amounts of O_2 , which correspond to $\text{Fe}^{3+}/(\text{Fe}^{3+} + \text{Fe}^{2+})$ ratios of 0.1–0.5 in the sediment. However, we do not find any considerable effect of varying $f\text{O}_2$ on the produced melt composition and the relative proportion of major minerals (Cpx+Grt) vs. silicate melt.

Fig. S7 shows the P – T phase relations obtained at $\text{Fe}^{3+}/(\text{Fe}^{3+} + \text{Fe}^{2+}) = 0.1$. The obtained mineral assemblages were consistent with the experimental products obtained by Hermann and Spandler, (2008), who used GLOSS as the starting material at experimental conditions of 2.5–4.5 GPa and 600–1050 °C. Our modeling results also show that the produced melts contained 0.3–1.6 wt.% FeO, which are also consistent

with the experimental results of 0.4–1.2 wt. % FeO obtained by Hermann and Spandler (2008).

Sulfur was not included in the Perple_X model. The mass of residual sulfide during slab sediment melting was calculated by mass balance, using the degree of sediment melting, the S concentration in the bulk sediment (800 ppm), and the S concentration (200–2000 ppm) in the melt as a function of fO_2 .

8. Supplementary Fig. S1-7:

Fig. S1. Correlations between Re and S in organic-rich sediments. The positive correlations indicate that Re may be mainly hosted within pyrite in reduced sediments. See more details in the section “Pyrite is a major host for Re in reduced sediments”.

Fig. S2. Selected back-scattered electron images of experimental products. (A) Run XS-03: double-capsule design used in this study showing the inner Au capsule containing the silicate melt and pyrrhotite (Po), and the outer Pt₉₅Rh₅ capsule. In the space between the inner and outer capsule, MgO powder was filled. At the bottom of the outer capsule, a layer of oxygen buffer materials and H₂O were loaded, which were separated from the inner capsule by a thin Pt disc (Pt divider). (B) BSE image of the coexisting Po and silicate melt from run XS-11. (C) BSE image of run XS-09 showing coexisting Po, silicate melt, garnet (Grt) and graphite in an Au capsule. (D) Close-up view of the garnet, silicate melt and Po shown in (C). (E) Close-up view of the Po inclusions/nuggets (2–10 μm) in the silicate melt in run XS-09. Note that large areas of silicate melt are free of Po inclusions. (F) Close-up view of the silicate glass that is free of Po inclusions/nuggets in run XS-11.

Fig. S3. Time-resolved LA-ICP-MS signals of Re and other elements in the quenched silicate melt, pyrrhotite and graphite. The signals of Re in both silicate melt and pyrrhotite are constant (A and C: run XS-02; B and D: run XS-08). E: The weak signal of Re in graphite indicates negligible Re dissolved in graphite.

Fig. S5. Measured $\log (D_{Re}^{po/sm})$ vs. predicted $\log (D_{Re}^{po/sm})$ using Eq. (1) in the main text. Note that measured $\log (D_{Re}^{po/sm})$ and predicted $\log (D_{Re}^{po/sm})$ agree within 0.3 log units.

Fig. S6. The plot of measured $D_{Re}^{po/sm}$ as a function of the Re concentration in Po. The lack of any dependence of $D_{Re}^{po/sm}$ on the Re concentration in Po implies that $D_{Re}^{po/sm}$ obey Henry's law.

Fig. S7. Pressure–temperature (P – T) pseudosections for the melting of slab sediment (GLOSS). The solidus is shown by the thick black line. Amph–amphibole; Qz–quartz; Pl–plagioclase; Grt–garnet; Kfs–K-feldspar; Ky–kyanite; Ms–muscovite; Rt–rutile; Coe–coesite; Lws–lawsonite; Cpx–clinopyroxene; Spn–sphene; Ilm–ilmenite; Zo–zoisite.

9. Supplementary Tables S1-6

Table S1. Major element composition of the starting silicate.

Table S2. Summary of the experimental conditions and run products and the calculated partition coefficients for Re and Mo.

Table S3. Major and trace element composition of the quenched silicate melts (major elements in wt. %; trace elements in ppm).

Table S4. Major and trace element composition of pyrrhotite crystals (Fe and S in wt. %; trace elements in ppm).

Table S5. Major and trace element composition of garnet crystals.

Table S1. Major element composition of the starting silicate.

PMSC	SiO ₂	TiO ₂	Al ₂ O ₃	FeO _{tot}	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅	Total
Starting silicate	68.81	0.50	15.72	0.99	0.19	1.47	4.19	7.33	0.29	100.00
EPMA analysis	68.50	0.50	16.26	0.70	0.13	1.60	4.08	7.63	0.20	99.61
1-σ	0.21	0.01	0.07	0.06	0.02	0.12	0.10	0.16	0.02	0.26

Oxides in silicates are in wt. %.

Table S2. Summary of the experimental conditions and run products and the calculated partition coefficients for Re and Mo.

Exp. No	Temperature (°C)	Pressure (GPa)	Starting material	f_{O_2} buffer	$\log/\text{O}_2$ (ΔFMQ)	$\log/\text{S}_2$	Capsule	Run duration (h)	Phase assemblage	FeO_{tot} in		$D_{\text{Mo}}^{\text{po/sm}}$	1- σ	$D_{\text{Re}}^{\text{po/sm}}$	1- σ
										Glass	(wt. %)				
XS-01	1000	1	PMSC+Sulfide+Anhy	SSO	2.00	0.75	Au	72	Glass+Po+Anhy	3.32		2.35	0.28	198	11.0
XS-02	1000	1	PMSC+Sulfide	Ni-NiO	0.04	0.39	Au+Pt ₉₅ Rh ₅	72	Glass+Po+Anhy	3.86		1.30	0.49	1050	91.5
XS-03	1000	1	PMSC+Sulfide	Ni-NiO	-1.25	0.53	Au+Pt ₉₅ Rh ₅	72	Glass+Po	1.72		13.7	8.29	8052	6327
XS-04	1000	1	PMSC+Sulfide	Re-ReO ₂	1.29	0.36	Au+Pt ₉₅ Rh ₅	72	Glass+Po	1.56		6.67	1.30	476	36.0
XS-05	1000	1	PMSC+Sulfide+Graphite	CCO	-1.34	-1.31	Au	72	Glass+Po+Graphite	0.52		44.5	19.8	25297	8766
XS-06	1000	2	PMSC+Sulfide+Graphite	CCO	-0.86	-1.34	Au	72	Glass+Po+Graphite	4.94		22.7	5.62	10089	4617
XS-07	1000	2	PMSC+Sulfide	-		1.39	Au	72	Glass+Po	3.74		2.64	0.36	861	158
XS-08	1000	2	PMSC+Sulfide+Anhy	SSO	2.00	0.87	Au	72	Glass+Po+Anhy	3.46		2.93	0.27	1104	176
XS-09	1000	3	PMSC+Sulfide+Graphite	CCO	-0.39	-0.44	Au	72	Glass+Po+Graphite+Grt	2.67		53.5	10.4	12222	6966
XS-10	1000	3	PMSC+Sulfide+Anhy	SSO	2.00	1.00	Au	72	Glass+Po+Anhy+Grt	2.39		8.21	1.07	4801	2134
XS-11	950	1	PMSC+Sulfide+Anhy	SSO	2.00	0.64	Au	90	Glass+Po+Anhy	2.36		5.51	1.32	993	93.3
XS-12	950	1	PMSC+Sulfide+Graphite	CCO	-1.22	-1.77	Au	90	Glass+Po+Graphite	1.61		55.2	21.2	20092	8062
XS-13	1080	2	PMSC+Sulfide+Anhy	SSO	2.00	1.38	Au	72	Glass+Po+Anhy	9.05		0.78	0.24	276	55.3
XS-14	1080	2	PMSC+Sulfide+Graphite	CCO	-1.07	-0.44	Au	72	Glass+Po+Graphite	5.86		16.7	1.26	6213	4669
XS-15	1000	2	PMSC+Sulfide	Ni-NiO	-0.25	-0.63	Au+Pt ₉₅ Rh ₅	72	Glass+Po	2.45		22.3	2.92	4301	1108

PMSC: partial melts of subducted pelitic sediments (PMSC, Table S1) (Duncan and Dasgupta, 2014); Po: pyrrhotite; Anhy: anhydrite; Grt: garnet.

Table S3. Major and trace element composition of the quenched silicate melts (major elements in wt. %; trace elements in ppm).

	SiO ₂	TiO ₂	Al ₂ O ₃	FeO _{tot}	MgO	CaO	Na ₂ O	K ₂ O	SO ₃	P ₂ O ₅	Total	H ₂ O	Cu	Mo	Ag	Re	Au
XS-01	60.57	0.41	14.96	3.32	0.10	0.85	2.34	6.10	0.61	0.11	89.40	10.60	0.47	5.72	0.046	5.39	1.72
1- σ	0.45	0.01	0.26	0.12	0.01	0.06	0.03	0.02	0.02	0.00	0.80	0.80	0.08	0.43	0.044	0.15	0.89
XS-02	60.16	0.42	14.81	3.86	0.08	0.96	2.63	6.35	0.33	0.10	89.71	10.29	0.69	8.53	0.020	1.01	1.96
1- σ	0.37	0.03	0.13	0.10	0.01	0.03	0.05	0.07	0.03	0.04	0.41	0.41	0.07	0.34	0.004	0.07	0.04
XS-03	67.32	0.47	15.94	1.72	0.16	0.76	3.50	7.09	0.15	0.19	97.31	2.69	0.53	1.10	0.043	0.15	0.27
1- σ	0.90	0.05	0.34	0.33	0.02	0.07	0.14	0.13	0.03	0.03	0.41	0.41	0.05	0.59	0.011	0.11	0.09
XS-04	63.41	0.49	15.29	1.56	0.10	1.05	2.91	6.42	0.14	0.11	91.49	8.51	0.48	2.64	0.019	1.59	1.16
1- σ	0.44	0.02	0.06	0.07	0.01	0.03	0.07	0.24	0.02	0.03	0.65	0.65	0.08	0.47	0.009	0.10	0.34
XS-05	65.73	0.49	16.04	0.52	0.08	0.79	2.55	6.76	0.06	0.09	93.12	6.88	0.36	0.56	0.010	0.05	0.44
1- σ	0.41	0.01	0.26	0.07	0.01	0.08	0.12	0.12	0.01	0.02	0.63	0.63	0.06	0.21	0.005	0.01	0.44
XS-06	58.70	0.44	14.62	4.94	0.09	1.03	2.62	6.23	0.06	0.12	88.89	11.12	1.23	0.71	0.008	0.04	1.28
1- σ	0.57	0.01	0.34	0.11	0.00	0.05	0.09	0.05	0.01	0.03	0.95	0.95	0.40	0.01	0.001	0.01	0.90
XS-07	60.98	0.24	14.40	3.74	0.06	0.56	2.24	6.09	0.80	0.12	89.23	10.77	0.72	6.98	0.036	0.81	0.92
1- σ	0.41	0.02	0.22	0.12	0.01	0.01	0.11	0.09	0.02	0.02	0.71	0.71	0.05	0.18	0.004	0.02	0.29
XS-08	61.65	0.28	14.57	3.46	0.09	0.79	2.80	6.55	0.63	0.13	90.96	9.04	0.77	5.37	0.026	0.54	0.73
1- σ	0.35	0.01	0.08	0.04	0.01	0.03	0.12	0.13	0.04	0.02	0.40	0.40	0.19	0.23	0.006	0.04	0.19
XS-09	61.53	0.37	14.10	2.67	0.05	0.57	2.62	7.01	0.06	0.13	89.18	10.82	0.73	0.46	0.010	0.03	0.20
1- σ	0.56	0.01	0.15	0.07	0.00	0.03	0.16	0.12	0.02	0.03	0.71	0.71	0.03	0.04	0.003	0.01	0.05
XS-10	63.99	0.38	13.89	2.39	0.02	0.72	2.44	6.61	0.52	0.13	91.10	8.90	1.36	3.03	0.034	0.15	0.25
1- σ	0.26	0.02	0.15	0.08	0.01	0.05	0.08	0.15	0.05	0.02	0.33	0.33	0.36	0.14	0.025	0.02	0.15
XS-11	64.44	0.20	14.35	2.36	0.12	0.65	2.54	5.50	0.25	0.08	90.46	9.54	0.65	3.34	0.022	0.68	2.48
1- σ	0.19	0.03	0.15	0.16	0.01	0.02	0.08	0.08	0.05	0.02	0.07	0.07	0.04	0.72	0.009	0.06	0.03
XS-12	64.48	0.43	14.96	1.61	0.18	1.19	3.17	6.10	0.05	0.03	92.20	7.80	0.63	0.29	0.005	0.03	0.36
1- σ	0.70	0.03	0.15	0.56	0.03	0.14	0.10	0.05	0.02	0.02	0.31	0.31	0.06	0.10	0.007	0.01	0.34
XS-13	56.11	0.30	12.76	9.05	0.21	2.59	2.88	5.10	1.36	0.07	90.43	9.57	0.53	12.85	0.050	3.44	4.15
1- σ	0.31	0.03	0.05	0.41	0.02	0.13	0.09	0.06	0.13	0.02	0.41	0.41	0.08	0.88	0.015	0.62	0.03
XS-14	59.52	0.42	14.14	5.86	0.37	1.37	3.17	5.74	0.11	0.10	90.78	9.22	0.29	0.89	0.010	0.19	2.98
1- σ	0.31	0.03	0.11	0.15	0.01	0.04	0.04	0.10	0.02	0.02	0.37	0.37	0.02	0.06	0.002	0.13	2.32
XS-15	60.74	0.46	14.19	2.45	0.24	1.33	3.08	6.02	0.09	0.08	88.69	11.31	0.52	0.83	0.010	0.21	1.48
1- σ	0.38	0.02	0.09	0.11	0.02	0.03	0.17	0.21	0.04	0.01	0.76	0.76	0.13	0.09	0.006	0.05	0.60

For each sample, typically 10–15 spots were analyzed by EPMA and 5–10 spots were analyzed by LA-ICP-MS, and 1- σ is the standard deviation based on the replicate analyses. The H₂O contents in the silicate melts were estimated by the deficit of EPMA totals from 100 wt.%.

Table S4. Major and trace element composition of pyrrhotite crystals^a (Fe and S in wt. %; trace elements in ppm).

	Fe	S	Total	log/S ₂	Cu	Mo	Ag	Re	Au
XS-01	59.31	39.22	98.53	0.75	183	13.5	1.82	1064	1525
1- σ	0.16	0.13	0.15	0.14	12.5	1.27	0.42	51.4	212
XS-02	59.63	39.34	98.97	0.39	174	11.1	1.38	1065	1248
1- σ	0.22	0.21	0.38	0.15	9.4	4.16	0.29	60.3	277
XS-03	59.37	38.95	98.31	0.53	110	15.0	5.25	1170	1880
1- σ	0.16	0.11	0.21	0.09	18.2	4.31	2.21	202	980
XS-04	59.79	39.00	98.79	0.36	243	17.6	1.63	758	931
1- σ	0.15	0.19	0.24	0.16	24.8	1.43	0.20	31.3	118
XS-05	60.87	37.78	98.65	-1.31	90.2	25.1	0.47	1154	396
1- σ	0.28	0.16	0.38	0.19	4.8	6.33	0.06	176	29.1
XS-06	60.91	37.79	98.70	-1.34	55.9	16.2	0.21	380	173
1- σ	0.15	0.36	0.35	0.40	1.8	4.01	0.08	127	12.9
XS-07	58.85	39.91	98.76	1.39	166	18.5	1.32	694	1544
1- σ	0.22	0.10	0.25	0.10	10.6	2.48	0.20	126	107
XS-08	59.10	39.26	98.37	0.87	163	15.7	1.18	598	1381
1- σ	0.19	0.15	0.20	0.15	9.6	1.28	0.18	81.7	122
XS-09	60.22	38.29	98.51	-0.44	156	24.8	0.32	335	316
1- σ	0.17	0.14	0.27	0.11	10.1	4.17	0.11	72.1	28.3
XS-10	59.12	39.47	98.60	1.00	156	24.9	1.02	731	1450
1- σ	0.18	0.33	0.38	0.23	13.9	3.04	0.15	305	184
XS-11	59.03	39.32	98.35	0.64	199	18.4	1.10	679	1030
1- σ	0.15	0.26	0.27	0.21	26.6	1.91	0.22	23.4	172
XS-12	60.95	37.77	98.72	-1.77	111	16.1	0.23	625	124
1- σ	0.25	0.12	0.29	0.20	6.7	2.31	0.12	44.8	16.3
XS-13	59.11	39.38	98.49	1.38	197	10.0	1.67	950	1963
1- σ	0.21	0.30	0.43	0.17	37.2	3.01	0.43	83.7	225
XS-14	60.78	38.03	98.81	-0.44	64.3	14.8	0.27	1188	425
1- σ	0.21	0.20	0.30	0.22	3.0	0.37	0.13	371	24.5
XS-15	59.87	37.85	97.72	-0.63	131	18.6	0.24	891	214
1- σ	0.17	0.13	0.08	0.22	4.4	1.26	0.10	29.9	3.34

a: in ppm for Cu, Mo, Ag, Re and Au and in wt. % for other elements.

For each sample, typically 10–15 spots were analyzed by EPMA and 8–10 spots were analyzed by LA-ICP-MS, and 1- σ is the standard deviation based on the replicate analyses.

Table S5. Major and trace element composition of garnet crystals^a.

Garnet	SiO ₂	Al ₂ O ₃	FeO _{tot}	MgO	CaO	MnO	Total	Re	$D_{Re}^{grt/sm}$
XS-09	36.53	20.11	37.46	0.93	4.86	0.03	99.93	0.015	0.55
1- σ	0.44	1.08	1.11	0.36	0.64	0.01	0.73	0.000	0.29
XS-10	37.11	20.20	37.28	1.16	5.35	0.12	101.23	0.015	0.10
1- σ	0.06	1.25	0.00	0.04	0.42	0.06	0.88	0.006	0.04

a: in ppm for Re and in wt. % for other elements.

For each sample, typically 5–10 spots were analyzed by EPMA and 2–5 spots were analyzed by LA-ICP-MS, and 1- σ is the standard deviation based on the replicate analyses.

The chemical formula of garnet is about (Mg_{0.11}Ca_{0.43}Fe_{2.44})Al₂(SiO₄)₃.

Table S6. Modelling Re behavior during slab sediment melting at 3 GPa (note that we used a total Re abundance of 100 ppb in the starting sediment).

Pressure (GPa)	FeO (wt. %)	T (°C)	Melt proportion (wt. %)	Garnet in residues (wt. %)	Cpx in residues (wt. %)	SCSS in melt (ppm)				S in residues (ppm)			
						FMQ+2	FMQ+1	FMQ	FMQ-2	FMQ+2	FMQ+1	FMQ	FMQ-2
3	0.32	881	0.12	14	34	2000	700	500	200	799	800	800	801
3	0.34	883	3.11	16	34	2000	700	500	200	762	803	810	819
3	0.34	884	6.84	17	34	2000	700	500	200	712	807	822	844
3	0.35	886	11.15	19	33	2000	700	500	200	649	813	838	875
3	0.32	890	18.81	22	33	2000	700	500	200	522	823	869	939
3	0.39	894	19.24	22	33	2000	700	500	200	514	824	871	943
3	0.35	898	19.74	23	33	2000	700	500	200	505	825	874	948
3	0.37	905	20.62	23	33	2000	700	500	200	488	826	878	956
3	0.37	913	21.63	24	33	2000	700	500	200	469	828	883	966
3	0.32	920	22.74	25	33	2000	700	500	200	447	829	888	977
3	0.36	928	24.06	26	33	2000	700	500	200	420	832	895	990
3	0.38	935	25.28	26	33	2000	700	500	200	394	834	901	1003
3	0.37	943	26.59	27	33	2000	700	500	200	365	836	909	1017
3	0.34	950	29.08	28	35	2000	700	500	200	308	841	923	1046
3	0.36	958	30.85	29	35	2000	700	500	200	265	845	934	1068
3	0.36	965	31.65	29	35	2000	700	500	200	244	846	939	1078
3	0.37	980	33.19	30	35	2000	700	500	200	204	850	949	1098
3	0.42	988	34.16	31	34	2000	700	500	200	177	852	956	1111
3	0.41	995	35.01	31	34	2000	700	500	200	154	854	962	1123
3	0.45	1003	35.96	31	34	2000	700	500	200	126	856	968	1137
3	0.48	1010	36.69	31	34	2000	700	500	200	105	858	974	1148
3	0.63	1025	38.34	31	34	2000	700	500	200	54	862	987	1173
3	0.73	1040	40.16	31	35	2000	700	500	200	0	867	1001	1203
3	1.09	1070	44.09	30	35	2000	700	500	200	0	879	1037	1273
3	1.61	1100	48.39	29	36	2000	700	500	200	0	894	1081	1363

Table S6 (continued)

$D_{Re}^{mineral/sm}$				$D_{Re}^{po/sm}$				Bulk D_{Re}				Re in melt (ppb)			
FMQ+2	FMQ+1	FMQ	FMQ-2	FMQ+2	FMQ+1	FMQ	FMQ-2	FMQ+2	FMQ+1	FMQ	FMQ-2	FMQ+2	FMQ+1	FMQ	FMQ-2
0.016	0.018	0.089	0.242	21488	50372	118083	648917	47.2	111	260	1429	2.12	0.90	0.39	0.07
0.017	0.019	0.095	0.247	20554	48183	112951	620713	43.1	106	252	1399	2.39	0.97	0.41	0.07
0.019	0.021	0.103	0.254	20283	47548	111465	612543	39.7	106	252	1422	2.70	1.02	0.43	0.08
0.021	0.022	0.111	0.261	19531	45785	107330	589823	34.9	102	247	1420	3.21	1.10	0.45	0.08
0.024	0.026	0.128	0.275	20909	49016	114906	631455	30.0	111	275	1631	4.07	1.11	0.45	0.08
0.024	0.026	0.128	0.276	17550	41140	96442	529988	24.8	93.2	231	1375	4.94	1.32	0.53	0.09
0.024	0.026	0.130	0.277	18892	44288	103820	570536	26.3	100	250	1487	4.70	1.24	0.50	0.08
0.025	0.027	0.133	0.280	17767	41649	97635	536544	23.9	94.6	236	1411	5.22	1.33	0.53	0.09
0.026	0.027	0.136	0.284	17320	40602	95180	523050	22.4	92.4	231	1389	5.64	1.38	0.55	0.09
0.026	0.028	0.140	0.288	19191	44989	105465	579571	23.6	102.6	258	1557	5.42	1.26	0.50	0.08
0.027	0.029	0.144	0.293	17327	40619	95221	523278	20.0	92.9	235	1425	6.47	1.41	0.56	0.09
0.028	0.029	0.147	0.296	16161	37886	88813	488063	17.5	86.9	220	1346	7.48	1.53	0.61	0.10
0.029	0.031	0.153	0.301	16073	37678	88325	485383	16.2	86.7	221	1358	8.24	1.57	0.62	0.10
0.030	0.031	0.157	0.314	16988	39825	93358	513040	14.4	92.1	237	1476	9.51	1.52	0.59	0.10
0.031	0.032	0.162	0.321	15878	37222	87258	479517	11.6	86.5	224	1408	12.0	1.66	0.64	0.10
0.031	0.033	0.164	0.322	15620	36617	85838	471712	10.5	85.3	222	1398	13.3	1.71	0.66	0.10
0.032	0.034	0.168	0.324	14709	34480	80830	444192	8.28	80.6	211	1342	17.1	1.85	0.71	0.11
0.032	0.034	0.170	0.325	12998	30471	71431	392540	6.37	71.4	188	1200	22.0	2.11	0.81	0.13
0.033	0.035	0.173	0.326	12943	30341	71127	390873	5.50	71.3	188	1208	25.5	2.14	0.81	0.13
0.033	0.034	0.172	0.326	11733	27504	64476	354321	4.10	64.8	172	1108	33.5	2.39	0.91	0.14
0.033	0.034	0.172	0.326	10955	25681	60203	330841	3.18	60.6	161	1045	42.0	2.58	0.98	0.15
0.033	0.035	0.173	0.327	8277	19403	45486	249963	1.26	46.0	124	807	86.1	3.48	1.31	0.20
0.032	0.034	0.170	0.327	7102	16649	39030	214485	0.03	39.7	108	710	238	4.14	1.54	0.24
0.032	0.034	0.169	0.326	4655	10913	25583	140587	0.03	26.4	73.1	493	218	6.58	2.42	0.36
0.031	0.033	0.163	0.326	3130	7337	17199	94513	0.03	18.1	51.3	354	200	10.2	3.71	0.55

Table S6 (continued)

Re in residues (ppb)				Re in Po (ppb)				Re in silicate minerals (ppb)			
FMQ+2	FMQ+1	FMQ	FMQ-2	FMQ+2	FMQ+1	FMQ	FMQ-2	FMQ+2	FMQ+1	FMQ	FMQ-2
100	100	100	100	45570	45493	45472	45460	0.03	0.02	0.03	0.02
103	103	103	103	49224	46702	46331	45801	0.04	0.02	0.04	0.02
107	107	107	107	54705	48306	47452	46235	0.05	0.02	0.04	0.02
112	112	112	113	62770	50298	48814	46746	0.07	0.02	0.05	0.02
122	123	123	123	85064	54282	51442	47682	0.10	0.03	0.06	0.02
123	124	124	124	86683	54504	51587	47734	0.12	0.03	0.07	0.02
123	124	124	125	88834	54797	51774	47798	0.12	0.03	0.07	0.02
125	126	126	126	92734	55297	52094	47907	0.13	0.04	0.07	0.03
126	127	127	128	97674	55884	52468	48034	0.14	0.04	0.08	0.03
128	129	129	129	103951	56570	52897	48177	0.14	0.04	0.07	0.02
130	131	132	132	112155	57364	53396	48343	0.18	0.04	0.08	0.03
131	133	134	134	120965	58117	53864	48498	0.21	0.05	0.09	0.03
133	136	136	136	132425	58973	54389	48668	0.24	0.05	0.09	0.03
137	140	141	141	161573	60678	55419	48994	0.28	0.05	0.09	0.03
139	144	144	145	190911	61921	56162	49227	0.37	0.05	0.10	0.03
140	146	146	146	207858	62497	56502	49332	0.41	0.06	0.11	0.03
141	149	149	150	250986	63641	57172	49537	0.54	0.06	0.12	0.04
140	151	151	152	286426	64335	57582	49664	0.71	0.07	0.14	0.04
140	153	153	154	329722	65003	57966	49779	0.84	0.07	0.14	0.04
137	155	156	156	392876	65720	58384	49905	1.10	0.08	0.16	0.05
134	156	157	158	460082	66277	58706	50002	1.37	0.09	0.17	0.05
109	160	161	162	712733	67436	59395	50214	2.83	0.12	0.23	0.07
8	164	166	167	0	68859	60216	50457	7.68	0.14	0.26	0.08
7	174	177	179	0	71765	61931	50970	6.97	0.22	0.41	0.12
6	184	190	193	0	74812	63791	51527	6.18	0.33	0.61	0.18

Table S6 (continued)

Re in melt/Total Re				Re in Po/Total Re				Re in milicate minerals/Total Re			
FMQ+2	FMQ+1	FMQ	FMQ-2	FMQ+2	FMQ+1	FMQ	FMQ-2	FMQ+2	FMQ+1	FMQ	FMQ-2
0.0000	0.0000	0.0000	0.0000	0.9996	0.9998	0.9997	0.9998	0.0003	0.0002	0.0003	0.0002
0.0007	0.0003	0.0001	0.0000	0.9989	0.9995	0.9995	0.9998	0.0004	0.0002	0.0004	0.0002
0.0018	0.0007	0.0003	0.0001	0.9977	0.9991	0.9993	0.9998	0.0005	0.0002	0.0004	0.0002
0.0036	0.0012	0.0005	0.0001	0.9958	0.9986	0.9990	0.9997	0.0006	0.0002	0.0004	0.0002
0.0077	0.0021	0.0008	0.0001	0.9916	0.9977	0.9987	0.9997	0.0008	0.0002	0.0005	0.0002
0.0095	0.0025	0.0010	0.0002	0.9895	0.9972	0.9984	0.9996	0.0010	0.0003	0.0006	0.0002
0.0093	0.0024	0.0010	0.0002	0.9898	0.9973	0.9985	0.9996	0.0009	0.0003	0.0005	0.0002
0.0108	0.0027	0.0011	0.0002	0.9882	0.9970	0.9983	0.9996	0.0010	0.0003	0.0006	0.0002
0.0122	0.0030	0.0012	0.0002	0.9867	0.9967	0.9982	0.9996	0.0011	0.0003	0.0006	0.0002
0.0123	0.0029	0.0011	0.0002	0.9866	0.9969	0.9983	0.9996	0.0011	0.0003	0.0005	0.0002
0.0156	0.0034	0.0013	0.0002	0.9831	0.9963	0.9980	0.9996	0.0013	0.0003	0.0006	0.0002
0.0189	0.0039	0.0015	0.0003	0.9795	0.9958	0.9978	0.9995	0.0016	0.0003	0.0007	0.0002
0.0219	0.0042	0.0016	0.0003	0.9763	0.9955	0.9977	0.9995	0.0017	0.0004	0.0007	0.0002
0.0277	0.0044	0.0017	0.0003	0.9703	0.9952	0.9976	0.9995	0.0020	0.0003	0.0007	0.0002
0.0371	0.0051	0.0020	0.0003	0.9604	0.9945	0.9973	0.9995	0.0025	0.0004	0.0007	0.0002
0.0421	0.0054	0.0021	0.0003	0.9551	0.9942	0.9972	0.9994	0.0028	0.0004	0.0007	0.0002
0.0566	0.0061	0.0023	0.0004	0.9397	0.9935	0.9969	0.9994	0.0036	0.0004	0.0008	0.0002
0.0753	0.0072	0.0028	0.0004	0.9200	0.9923	0.9963	0.9993	0.0047	0.0005	0.0009	0.0003
0.0892	0.0075	0.0029	0.0004	0.9054	0.9920	0.9962	0.9993	0.0054	0.0005	0.0009	0.0003
0.1204	0.0086	0.0033	0.0005	0.8726	0.9909	0.9957	0.9992	0.0070	0.0005	0.0010	0.0003
0.1541	0.0095	0.0036	0.0006	0.8372	0.9900	0.9954	0.9991	0.0087	0.0006	0.0011	0.0003
0.3301	0.0133	0.0050	0.0008	0.6524	0.9859	0.9936	0.9988	0.0174	0.0007	0.0014	0.0004
0.9541	0.0166	0.0062	0.0009	0.0000	0.9825	0.9922	0.9986	0.0459	0.0008	0.0016	0.0005
0.9610	0.0290	0.0107	0.0016	0.0000	0.9698	0.9870	0.9977	0.0390	0.0012	0.0023	0.0007
0.9681	0.0493	0.0179	0.0026	0.0000	0.9489	0.9789	0.9964	0.0319	0.0017	0.0031	0.0009

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