High molybdenum abundance in the ~2 Ga Zaonega Formation: Implications for seawater following the Lomagundi Excursion

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Background & objective

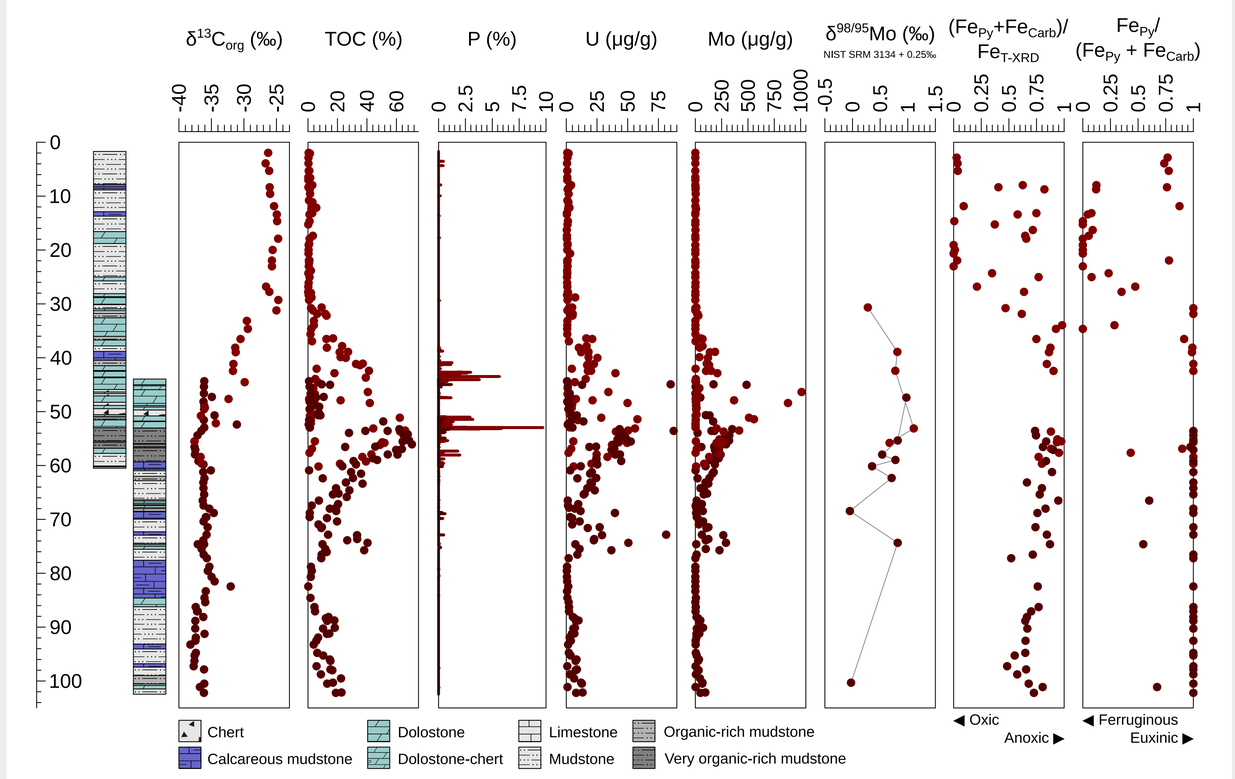
The enrichment and isotopic composition of redox-sensitive elements (RSE) in black shales are frequently used tools for estimating local and global marine redox conditions. For instance, Mo and U enrichments in the sedimentary record have been shown to increase after the Great Oxidation Event (GOE) and the Lomagundi Excursion (2.45-2.0 Ga). A decline in O_2 levels after 2.0 Ga is inferred to have caused a drop in marine RSE abundance [1]. However, it remains unclear how such trends are affected by basinal, rather than global conditions.

We have analysed RSE concentrations and Mo isotopes in a new 100-m section of the ~2 Ga Zaonega Formation (ZF), NW-Russia, in order to assess the importance of basinal versus global signals on RSE enrichment and to re-evaluate redox development in the critical ~2 Ga time interval which links the high-O_2 post-GOE and the low-O_2 Mesoproterozoic worlds.

Take-home points

- **Some of the highest Mo concentrations in the Precambrian (up to 1000 µg/g) suggest a robust marine Mo pool at ~2 Ga. This argues against a previously inferred collapse of the sulfate pool at ~2 Ga [2].**
- **Mo behaviour in the ZF mostly reflects open basin conditions, thus RSE cycling in the ZF likely records global marine trends.**
- **Lack of basinal watermass restriction w.r.t. Mo cycling, however, points to 1.11 ± 0.07‰ being an underestimate of marine $\delta^{98/95}$Mo.**
- **Retention of Mo in high-TOC pyrobitumen veins suggests that the majority of Mo in the ZF is bound to organic phases.**

Results



◄ Figure 1: $\delta^{13}C_{org}$, total organic carbon (TOC), P, U and Mo concentrations, $\delta^{98/95}$Mo and XRD-based Fe distribution in the studied section. $\delta^{13}C_{org}$ and Fe distribution from [3]. A lithology-based correlation is used to combine chemostratigraphic data from the two cores into a continuous section.

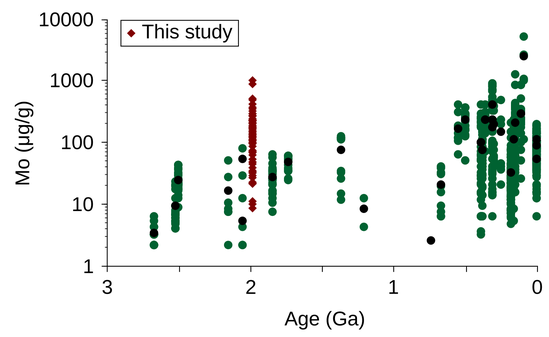


Figure 2: Secular trends in Mo concentrations in black shales. The ZF contains some of the highest Mo enrichments known in the Precambrian, suggesting a robust Mo pool. Modified from [1].

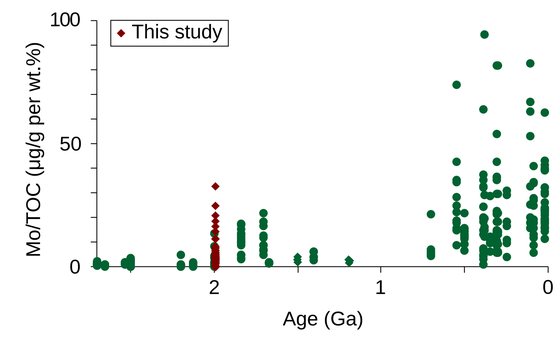


Figure 3: Secular trends in Mo/TOC ratios in black shales. These ratios likewise support a robust or even increased Mo pool at 2 Ga. Modified from [4].

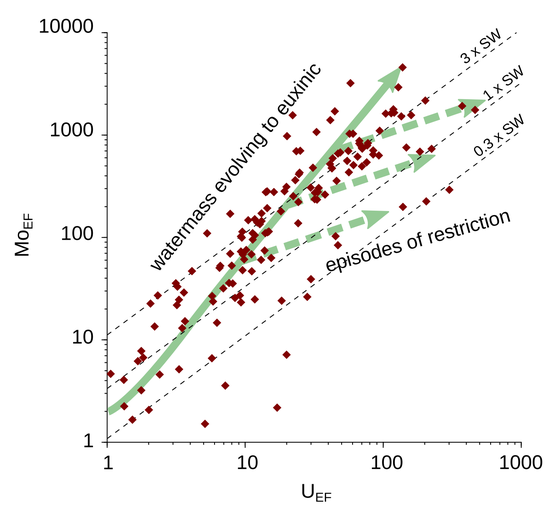


Figure 4: Crossplot of Mo and U enrichment factors (EF). The majority of the data follows a trend suggestive of increasing water-column hypoxia and sulfidity under non-restricted conditions [5]. Some scattered data possibly relate to Mo depletion in episodes of basinal restriction. Lack of restriction indicatesthat $\delta^{98/95}$Mo is likely fractionated from seawater.

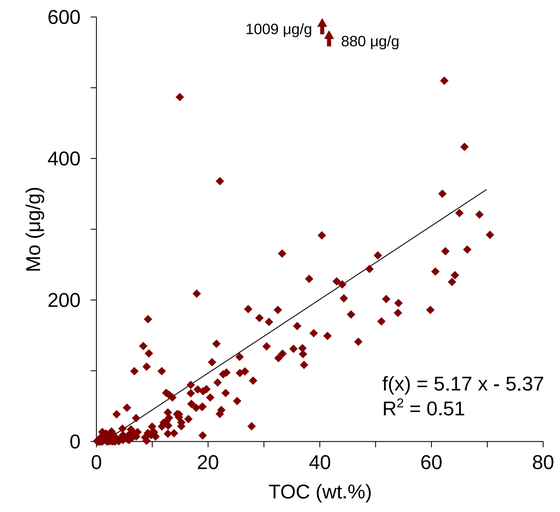
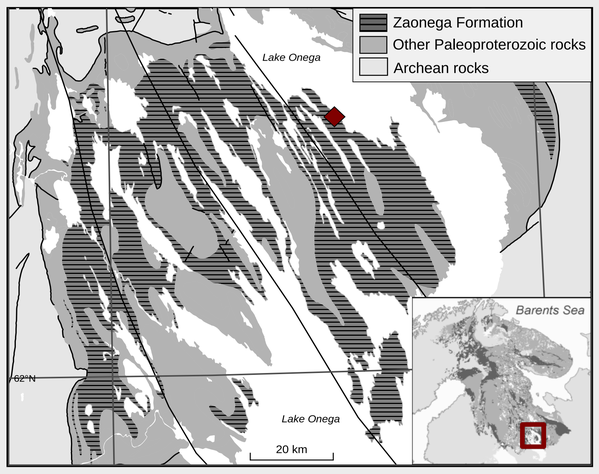


Figure 5: Crossplot of Mo concentrations versus TOC content. The strong correlation even at high TOC levels suggests the association of Mo with organic phases.

Study area



◄ Figure 6: Location of the studied cores in the context of the Onega basin, NW-Russia.

The ZF is a succession of exceptionally organic-rich (up to 90%) shales and carbonates interlayered with lava layers and tuffs. At ~2 Gyr old [6], the ZF overlies the Tulomozero Formation, which records the Lomagundi carbonate carbon isotope excursion. It defines the Shunga Event, an episode of enhanced organics accumulation.

References

[1] Robbins et al. 2016. Earth-Sci Rev 163, 323–348
[2] Scott et al. 2014. Earth Planet Sc Lett 389, 95–104.
[3] Paiste et al. 2017. In review.
[4] Scott et al. 2008. Nature 452, 456–459.
[5] Tribovillard et al. 2012. Chem Geol 324, 46–58.
[6] Martin et al. 2015. Earth Planet Sc Lett 424, 226–236.

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