Unravelling weathering, climate and the ocean redox-state in the wake of Earth's Great Oxidation Event (ca. 2.32–2.08 Ga): insights from the Pretoria Group (South Africa)

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Background & aim of the project

- The Paleoproterozoic Great Oxidation Event (GOE) and the Lomagundi Event (LE) mark major changes in the composition of Earth's atmosphere [1]
- The link between the GOE and the LE and continental weathering, climate fluctuations and changes in the marine redox-state are still poorly understood
- Sedimentary rocks of the Pretoria Group (Transvaal Supergroup, South Africa) offer a rare archive of these environmental perturbations
- Here, we report a high-resolution weathering and redox framework for this critical time interval using major and trace element data and stable Mo isotopes

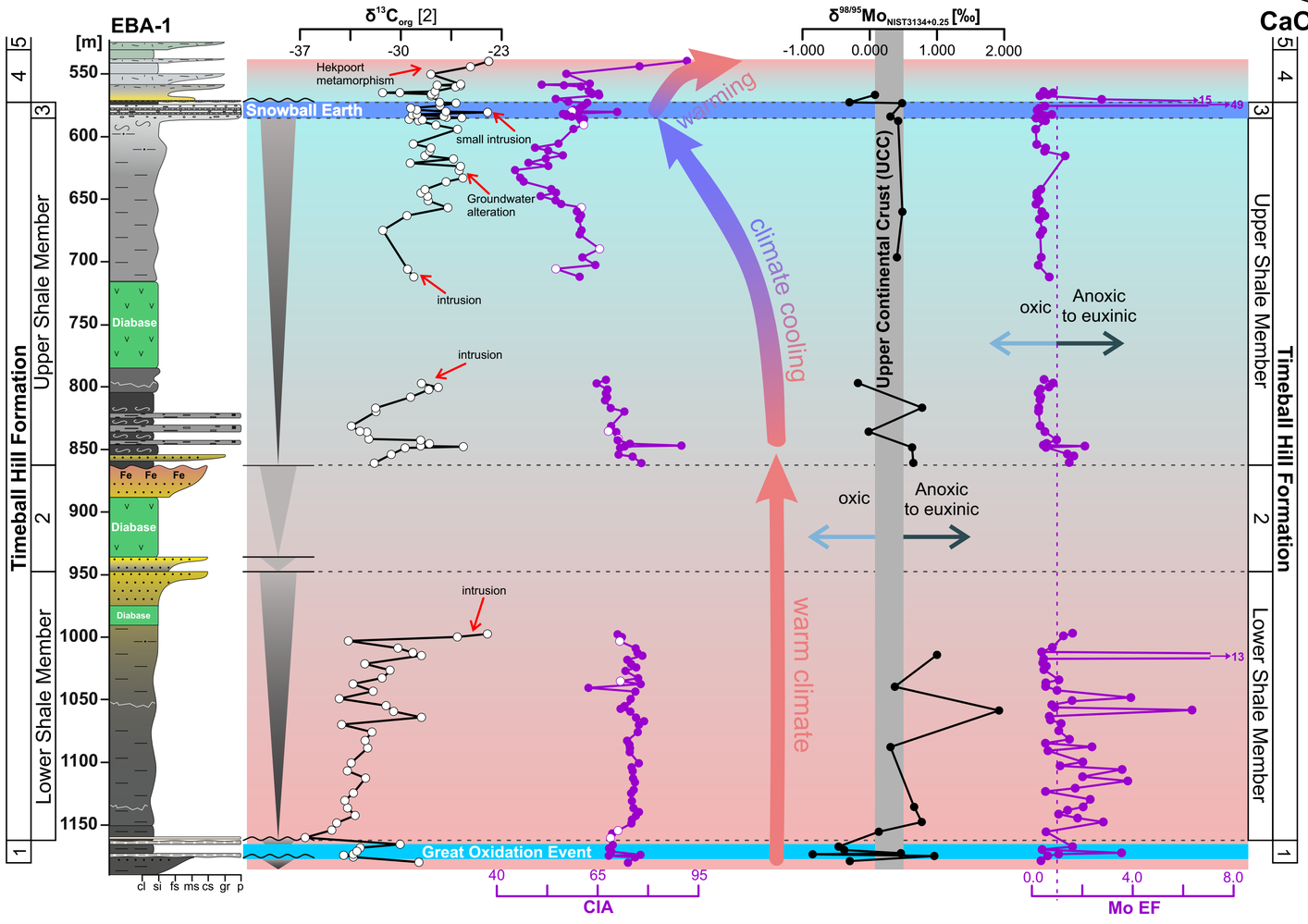
Results & discussion

- High CIA (**C**hemical **I**ndex of **A**lteration) values in the lower TBH reflect intense continental weathering and a warm climate, followed by a marked decrease in weathering intensity in the upper TBH, suggesting a cooling, culminating in deposition of the glacial Rietfonteindam Diamictite
- A renewed intense warming occurred in the Boshoek Formation, continuing into the Dwaalheuwel and Strubenskop formations, followed by a slight cooling during the LE (Silverton Formation)(?)
- Na+Ca loss = plagioclase breakdown in source area; later Mg+Fe+K loss= breakdown of pyroxene, biotite and K-feldspar
- High enrichment factors (EF) of Mo and high $\delta^{98/95}Mo_{NIST3134+0.25}$ values suggest temporal anoxia/euxinia in the lower Timeball Hill Formation, the following low values suggest predominantly oxic conditions before/during the LE

Simplified log of the EBA-1 drill core (below; modified after [2]) and of the BB-11 and LES-1 drill cores (on the right) with selceted geochemical proxies, empty symbols are data of [2]

1 Rooihoogte Formation 2 Klapperkop/Gatsrand Member 3 Rietfonteindam Diamictite

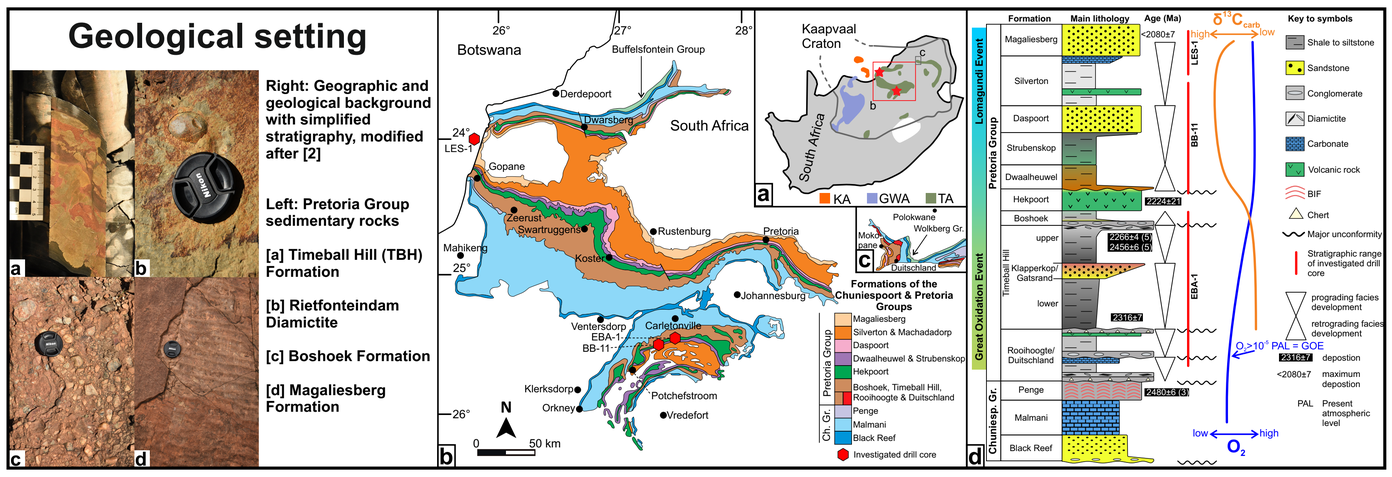
4 Boshoek Formation & Transitional Zone 5 Hekpoort Formation



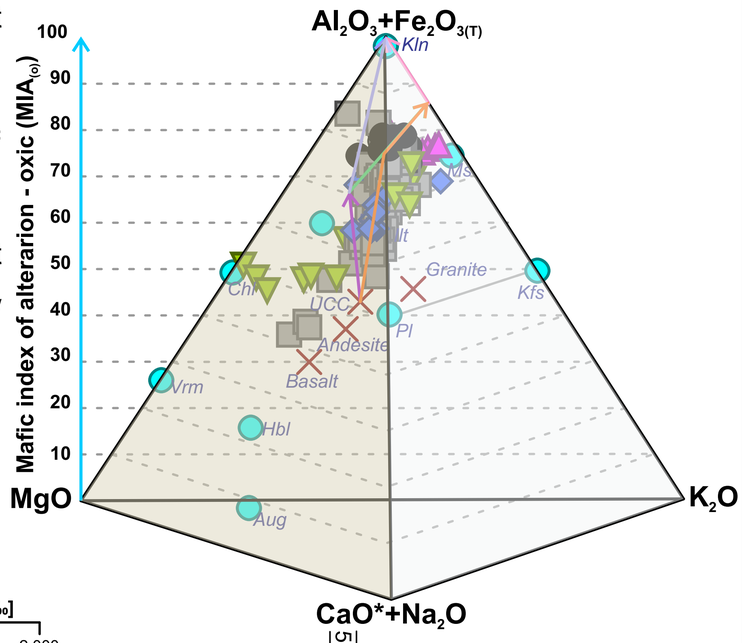
Conclusions & next steps

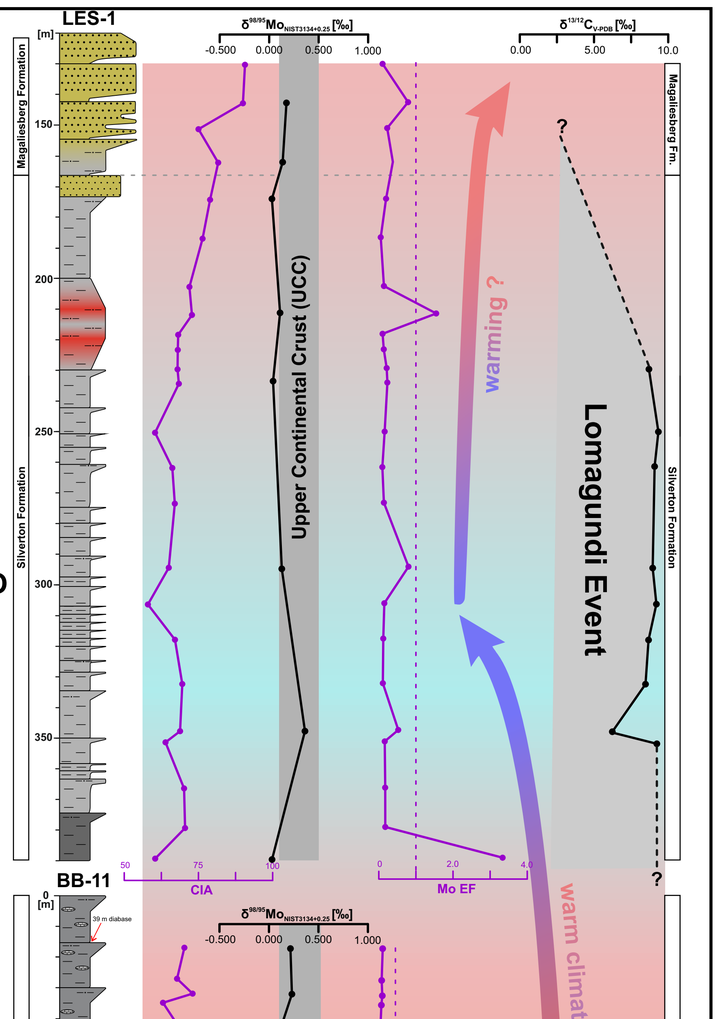
- Changes in continental weathering track climate fluctuations and rise of atmospheric O_2 probably triggered a Snowball Earth Event, followed by an intense warming
- Intense weathering led to a temporary increased nutrient flux to the ocean, intensifying primary productivity, further forcing atmospheric O_2 build-up with temporal oceanic anoxia/euxinia
- Next: Refinement of the redox framework for the GOE–LE transition, using stable Cr and W isotopes

Geological setting



Detailed weathering trends in a tetrahedral space after [3], exemplified by the EBA-1 drill core





Key to symbols

Minerals & potential source rocks

- Common mineral
- Igneous rock

Model weathering trends

- Ca+Na depletion
- Mg depletion (after Ca+Na depletion)
- Ca+Na > Mg (2:1) depletion
- K depletion (after Ca+Na(+Mg) depletion)
- Mg+K(+Fe) depletion (after Ca+Na depletion)

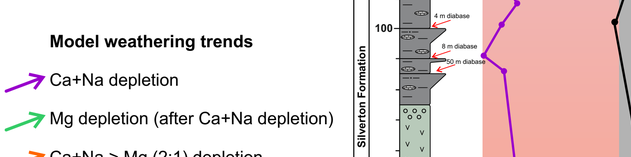
Sedimentary Rocks

- Boshoek Formation
- Rietfonteindam Diamictite
- Upper Shale Member
- Lower Shale Member
- Rooihoogte Formation

GEOLOGY *made friendly*

Ancient rocks & more; Earth's first breath

the no-jargon version of the science above



THE STORY IN 5 CHAPTERS

left = older → right = younger

1. **Warm & wet** — warm, wet world. Rock on land dissolves fast, high CIA
2. **The big freeze** — Rising O_2 likely helped Earth into a global glaciation – the Rietfonteindam Diamictite
3. **The sunrise** — Ice retreats, the world warms again, extreme weathering recorded in Dwaalheuwel Formation
4. **The bloom** — Weathering fed the ocean, fueling algae blooms. Intense atmospheric O_2 build-up
5. **Toxic ocean** — Now and then, (deep) water lost its oxygen and turned toxic. Metals recorded it

O_2 climate: warm | cold | hot | cool to warm?

How it all fits together

ONE-LINE TAKEAWAY

When earth learned to breathe, the land melted into the sea, climate changed and the oceans went toxic – and these rocks kept the receipts

REMEMBER
The GOE was Earth's first breath of O_2 = changed the whole planet

The Lomagundi Event = first massive accumulation of O_2 on Earth

TIP
high CIA = the rock weathered a lot, which usually means a warm & wet climate

WATCH OUT
It is called an oxidation event, but the (deep) ocean often stayed completly O_2-free for ages afterwards

CHEAT SHEET

- **GOE** — Earth's first breath of O_2
- **Euxinia/euxinic** — O_2-free, sulfide-rich (stinky) water
- **CIA/MIA** — how screwed-up is this rock?
- **Diamictite** — jumbled rock dumped by glaciers
- **EF** — how much metal piled up vs normal
- **Pretoria Group** — the rocks we read

References
[1] Farquhar et al. 2000; *Science*, 289, 756–758. [2] Coetzee, 2001; M.Sc. Thesis, University of Johannesburg, 220 pp.
[3] Babechuk & Fedo 2023; *Can. J. Earth Sci.*, 60, 839–864.

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