

The Times of Sand: Applying Cosmogenic ^{21}Ne to Examine the Brief Exposure Times of Quartz Sands throughout Sedimentary Cycles

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Abstract

The sedimentary cycle of quartz sand is comprised of the weathering of source rock, followed by erosion, deposition, then burial, and in some cases, lithification. Over geological timescales, quartz sands undergo several sedimentary cycles, with sandstones retaining evidence of previous cycles in various mineralogical and geochemical traces. These sedimentary cycles can span across timescales of hundreds of millions of years, with some sands holding evidence of the earliest rocks in Earth's history (e.g., Australian and Kalahari deserts). However, we have little knowledge of the timescales that sands spend exposed at the Earth's surface and how these compare to the timescales of sedimentary cycles. Unlike the more commonly used cosmogenic nuclides, cosmogenic ^{21}Ne is stable and can be used to study rates of surface processes in the deep geological past. We use cosmogenic ^{21}Ne to quantify exposure times at the surface from Lower Cretaceous and Miocene outcrops (Kurnub and Hazeva formations) and one active fluvial system (Colorado River). Although not devoid of drawbacks and limitations (i.e., diffusion out of the quartz crystal and high levels of non-cosmogenic ^{21}Ne in quartz), we are able to constrain exposure times at the surface to $<10^6$ years. Compared to the overall timescales of sedimentary cycles, evaluated using detrital zircon provenance data, exposure times at the surface are shorter by over an order of magnitude. These results demonstrate how in the context of sedimentary cycles, quartz sands spend the greater part of the time buried in fluvial systems sedimentary units (e.g., fluvial terraces, fans, and deltas) or at sedimentary basins. In comparison, the time that these sands spend at the surface during weathering, erosion, and deposition is strikingly brief.

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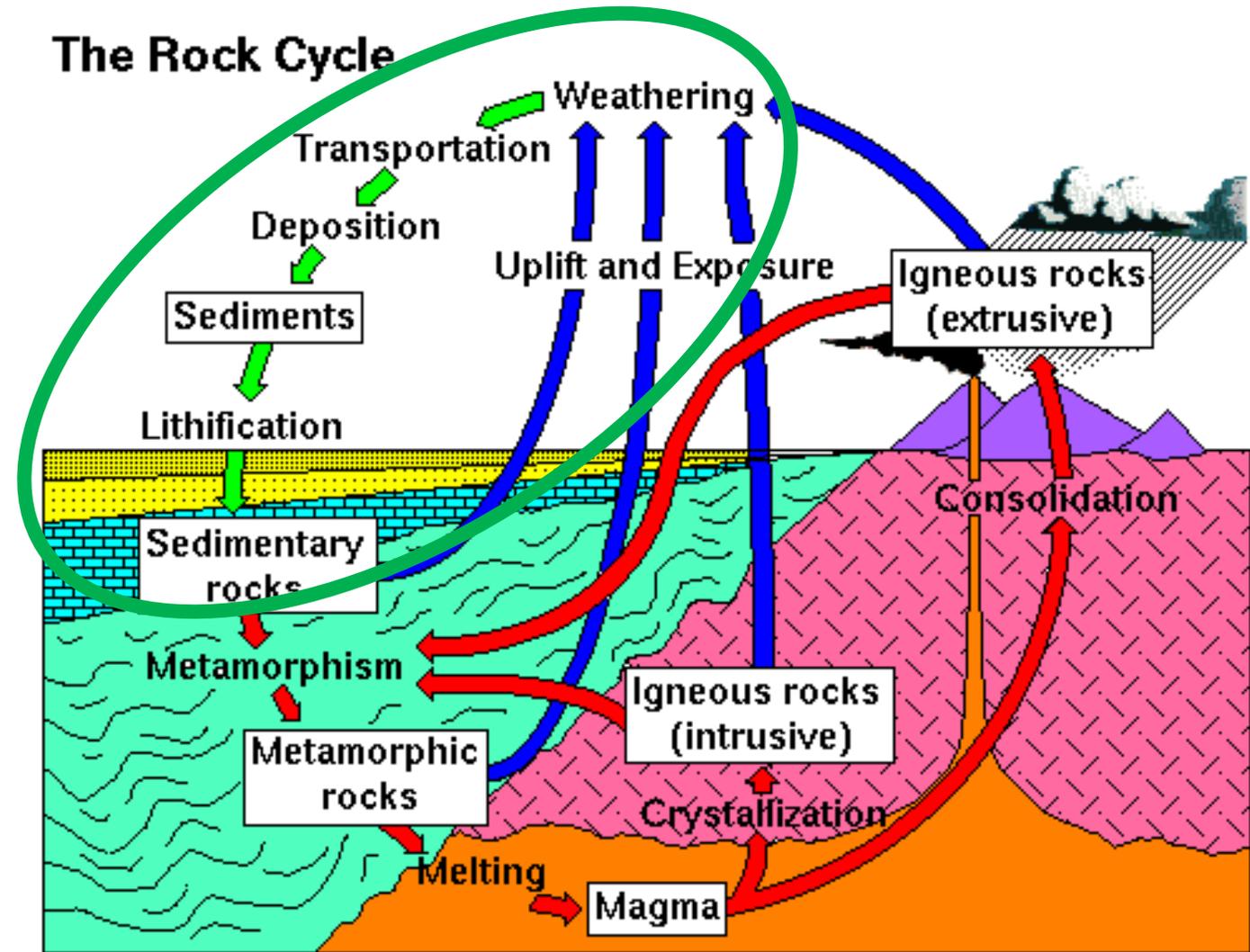
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Quantifying exposure over sedimentary cycles

- The sedimentary cycle includes all surface processes
- Quantifying rates of surface processes usually only focuses on one aspect of sedimentary cycle
- Examine the timescales of overall exposure at the surface during sedimentary cycles



Timescales of exposure over sedimentary cycles

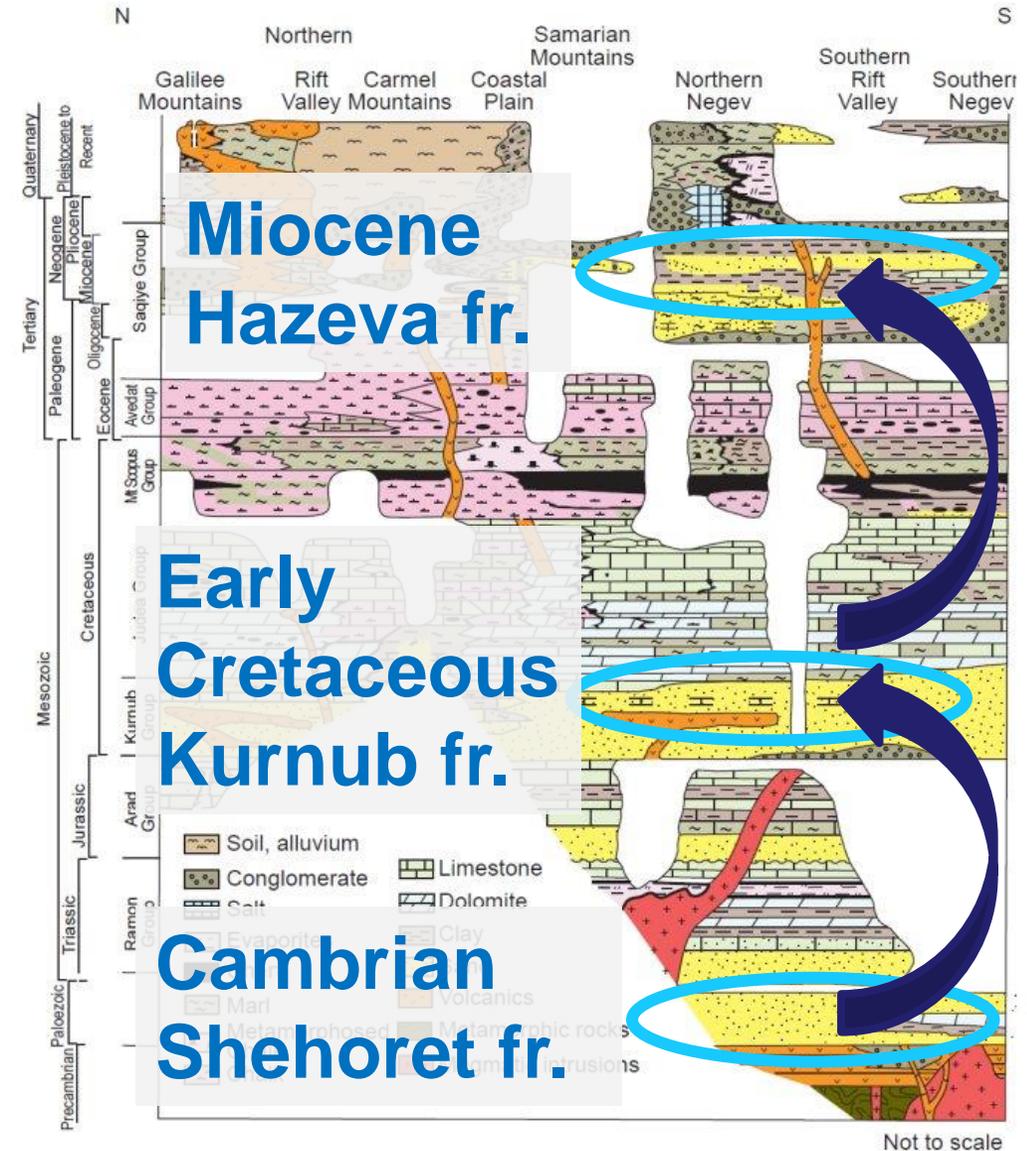
Questions and (somewhat obvious) answers

- What are the timescale of sedimentary cycles?
→ *Probably long exposure times...*
- How do these timescales compare to other processes in the rock cycle
→ *Probably shorter than most processes...*
- Can we give a quantitative answer?



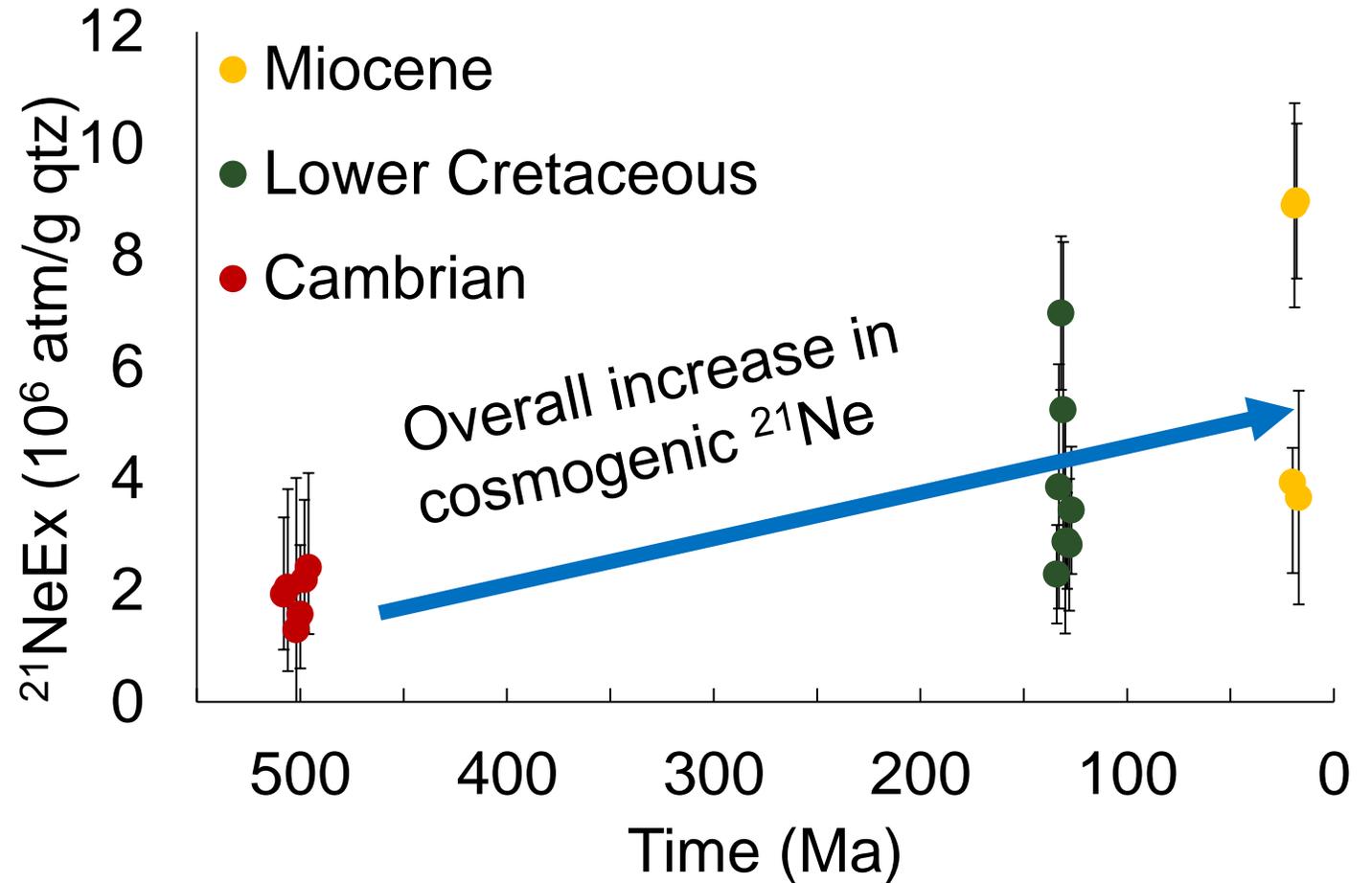
Sampling consecutive sedimentary sand units

- Sand in the Levant region was exposed, eroded, and re-deposited throughout the Phanerozoic
- This dataset allows us to follow exposure times of sediments throughout sedimentary cycles
- Using cosmogenic ^{21}Ne inheritance to follow exposure times of sediments



Consecutive sedimentary units – Levant

- ^{21}Ne corrected for diffusion based on depth and burial time
- Overall increase in cosmogenic ^{21}Ne concentrations
- ^{21}Ne concentrations translate to exposure times of 10^4 - 10^5 years

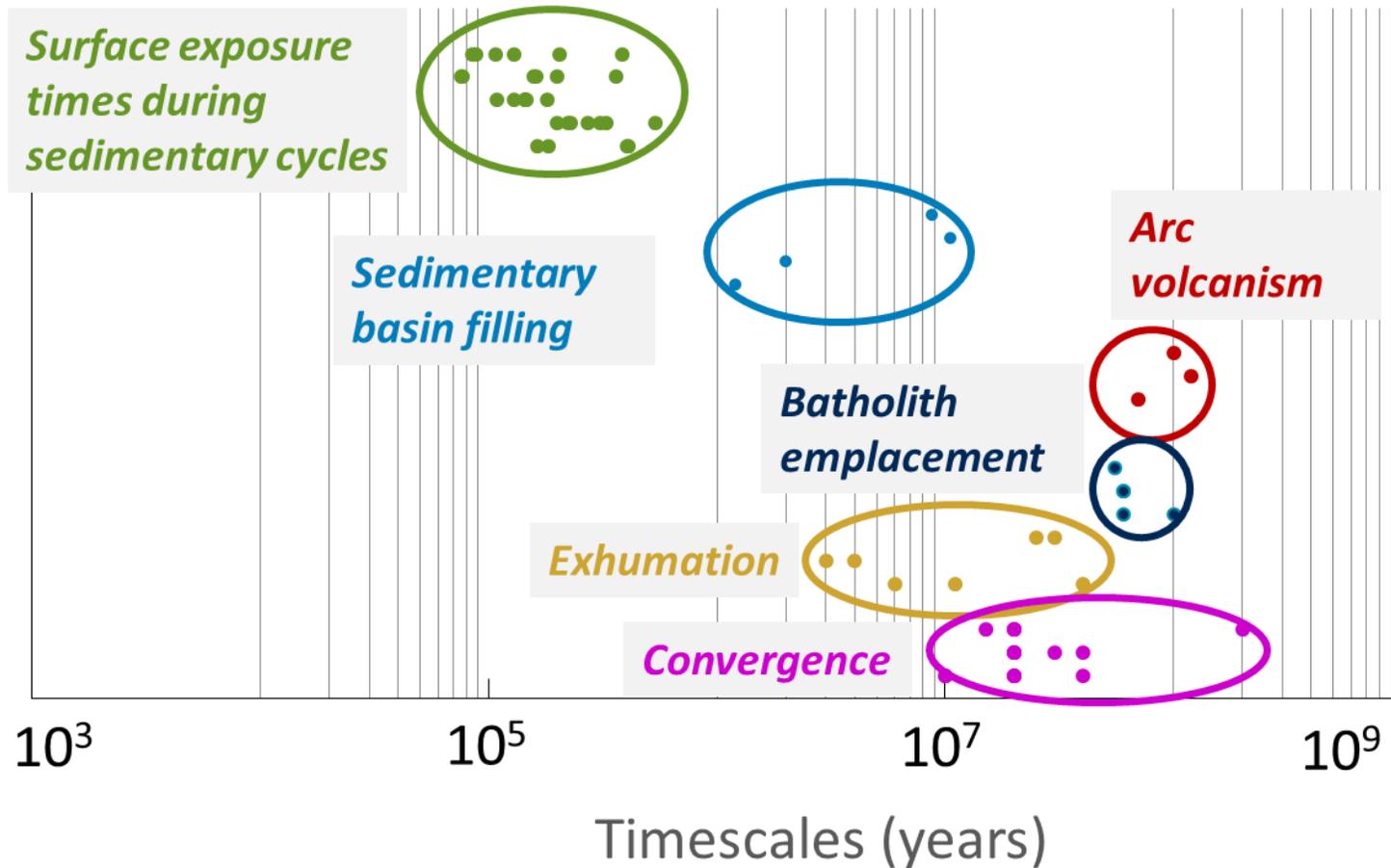


Sediments with cosmogenic inheritance

Levant Hazeva River – 18-20 Ma (Ben-Israel et al., 2020)	Lower Colorado River Current river – 0-5 Ma (Ben-Israel et al., in preparation)	Tibetan Plateau Pleistocene Fluvial terraces (Hetzel et al. 2002)
Provenance: Cambrian-Ordovician Arabo- Nubian sands (<500 Ma)	Provenance: Cambrian–Devonian to Cenozoic rocks of the Colorado Plateau (<500 Ma)	Provenance: Early Paleozoic metamorphic quartz veins (~500 Ma)
Simplified exposure history: ~60-600 kyr	Simplified exposure history: ~20-500 kyr	Simplified exposure history: ~40-200 kyr

- Timescales of total exposure at the surface $\sim 10^4$ - 10^5 years
- Exposure times of sediments are short compared to age of sediment

Take home messages



- Exposure times of sediments at the surface are 1-2 orders of magnitude short compared to most geological processes
- Sediments spend only a brief time exposed at the surface and most of the time buried

Email me with q's or ideas
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