

Neoproterozoic island arcs evolution and recycling in the northern Arabian-Nubian Shield: U-Pb-Hf-O isotopes in detrital zircon from Eilat metasediments

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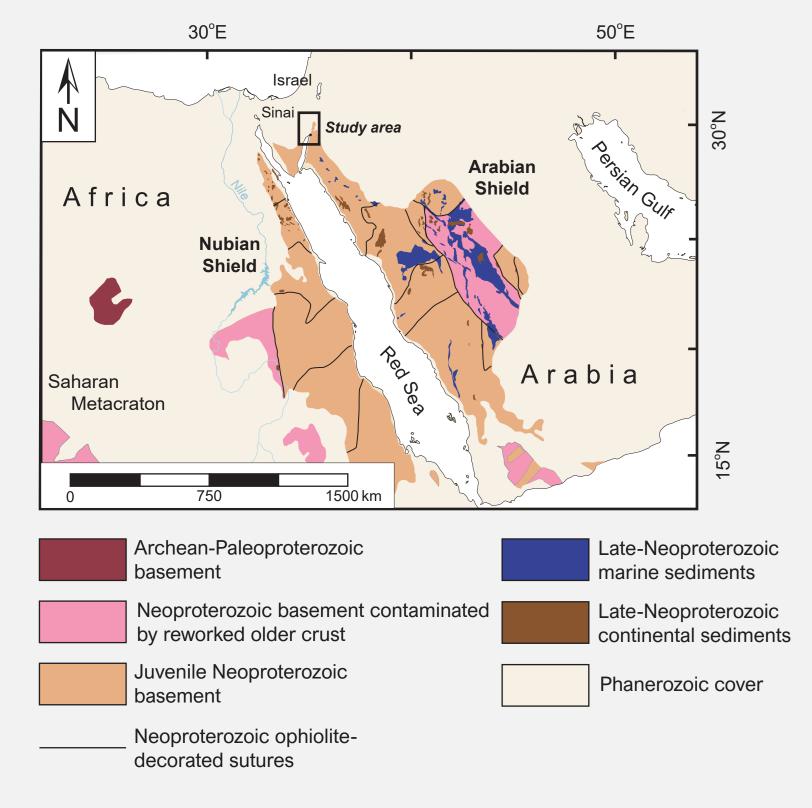
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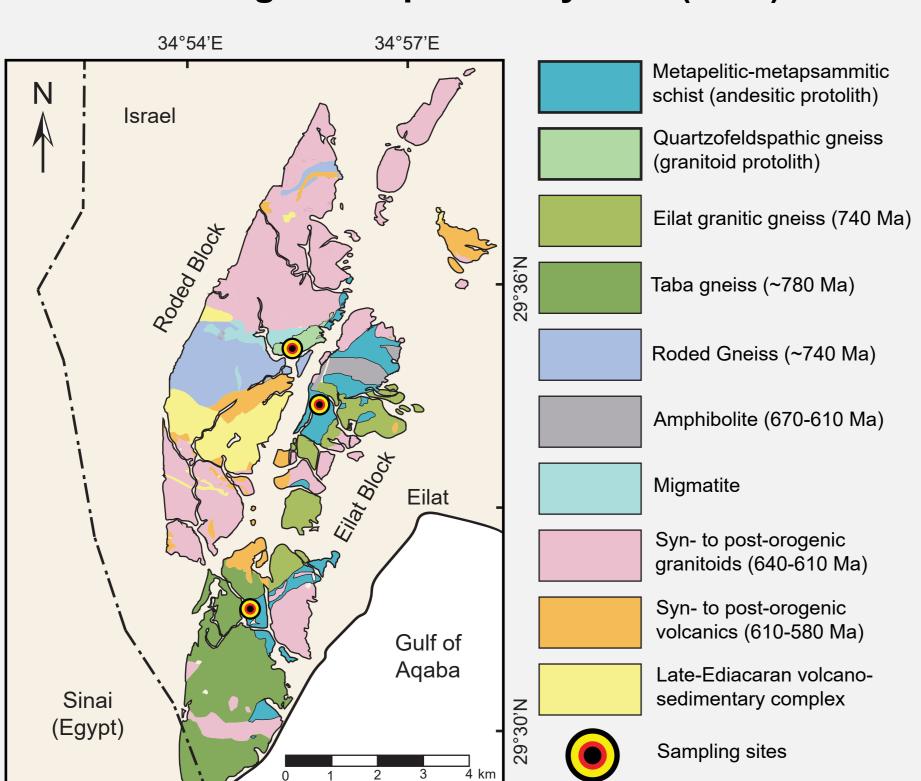
Introduction

- The Arabian-Nubian Shield is one of the largest Neoproterozoic juvenile continental crust provinces, formed by magmatism of intra-oceanic island arcs, followed by their accretion and by later orogenic and post-orogenic magmatism.
- Metasedimentary units of the Eilat Metamorphic Complex preserve sediments eroded from these island arcs. Thus, detrital zircons from schist and gneiss units of Eilat retain the chemical characteristics of their arc protoliths, reflecting arc magmas
- Coupled U-Pb-Hf-O analyses of these zircons enable to study the juvenile nature of the island arcs and the degree of crustal recycling involved in their formation.

Geological map of the Arabian-Nubian Shield

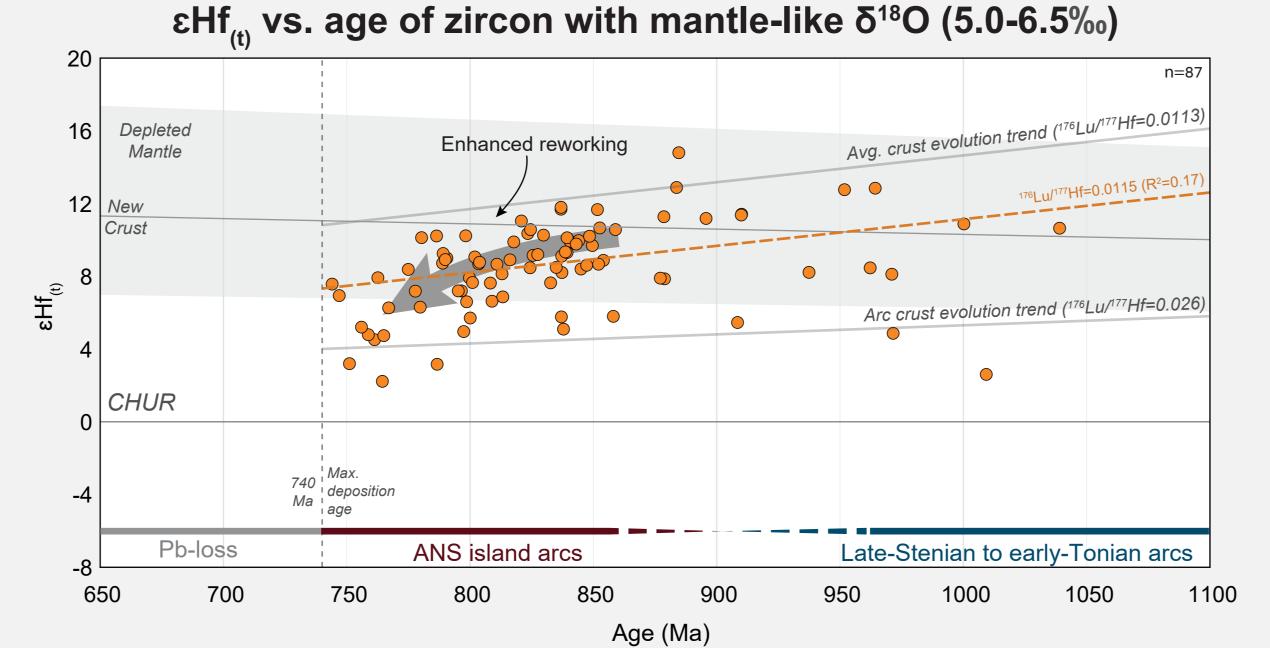


Geological map of study area (Eilat)



Hf isotopes in zircons with mantle-like δ¹⁸O (5.0-6.5‰)

- Zircons with mantle-like δ¹⁸O (5.0-6.5‰) represent crust that formed by melts that were not contaminated by supracrustal materials, better designating crustal evolution.
- Zircons with positive εHf_(t) values, mostly +6 to +12, primarily reflect juvenile Neoproterozoic crust formation.

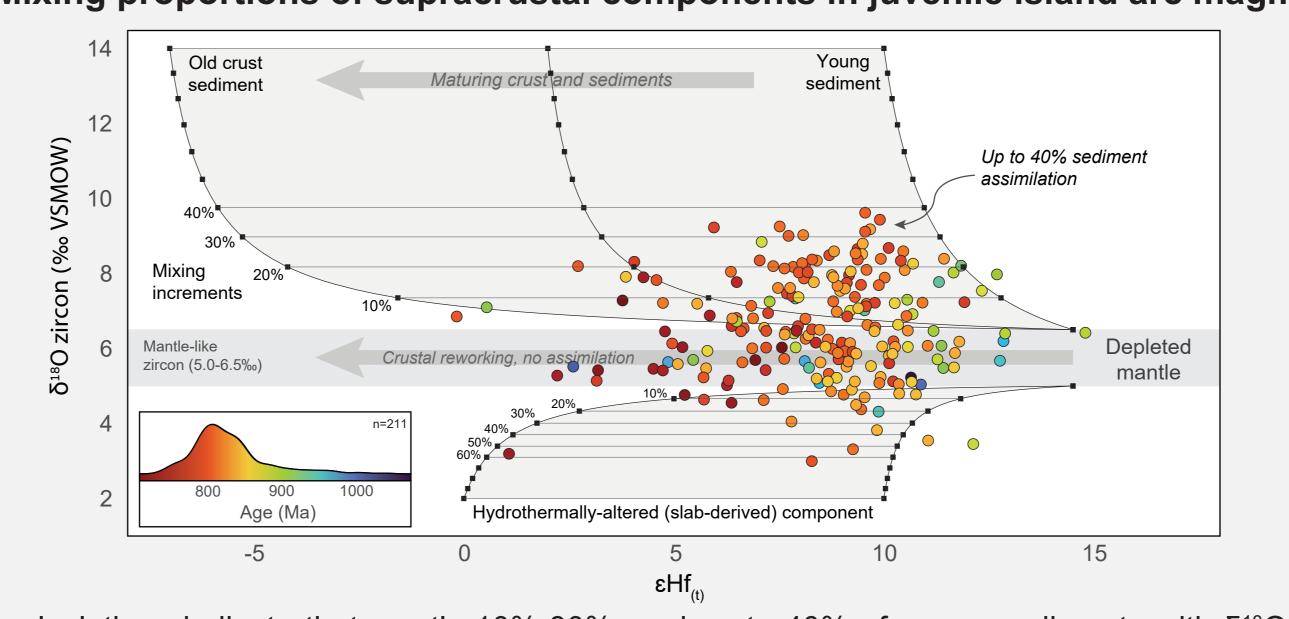


- Zircon grains with mantle-like δ¹⁸O values define a temporally decreasing trend of εHf_(t) values. Alongside positive εHf_(t), this trend suggests continuous reworking of immature, deep-seated island arc crust, concurrently with juvenile arc magmatism.
- At ~820 Ma εHf_{/+1} values drop beneath the New Crust trajectory (Dhuime et al., 2011), implying ~80 m.y. of enhanced crustal reworking of island arcs crust.
- The scarcity of zircon with low εHf_(t) values, in addition to just two Paleoproterozoic-age zircons found in Eilat schist, implies that only a minor amount of older (pre-Stenian) crust was reworked and incorporated into the island arc system, and that it evolved in a large oceanic basin disconnected from any continent.

Quantifying mixing

• The variety of δ¹⁸O and εHf_(t) values in zircon points to different components that were assimilated in juvenile melts. Thus, mixing is modelled as hybrid two-component mixing between mantle-derived juvenile melts with a fixed isotopic signature (or a short range of values), and each of the assimilated components. We explore several endmembers that represent assimilated components with compositions that gradually evolve over time, reflecting crustal maturation:(1) juvenile, intermediate age and old sediments; (2)

Mixing proportions of supracrustal components in juvenile island arc magmas



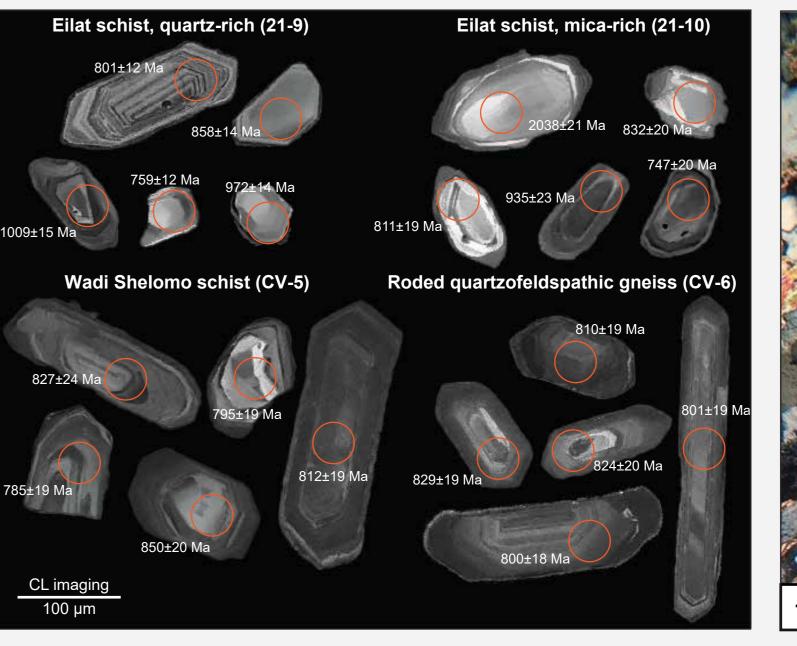
- Mixing calculations indicate that mostly 10%-30%, and up to 40% of young sediments with δ^{18} O value of 14‰ and εHf_(t) values of +2 to +10 are required to produce the observed values in studied zircons, demonstrating the importance of sediment recycling in the evolution of island arcs in the northern Arabian-Nubian Shield.
- Variations in mixing proportions, as well as diversity in isotopic values of O and Hf reflect a complex island arcs system that simultaneously experienced different degrees of recycling of crustal and supracrustal components, largely derived from the arcs system itself.

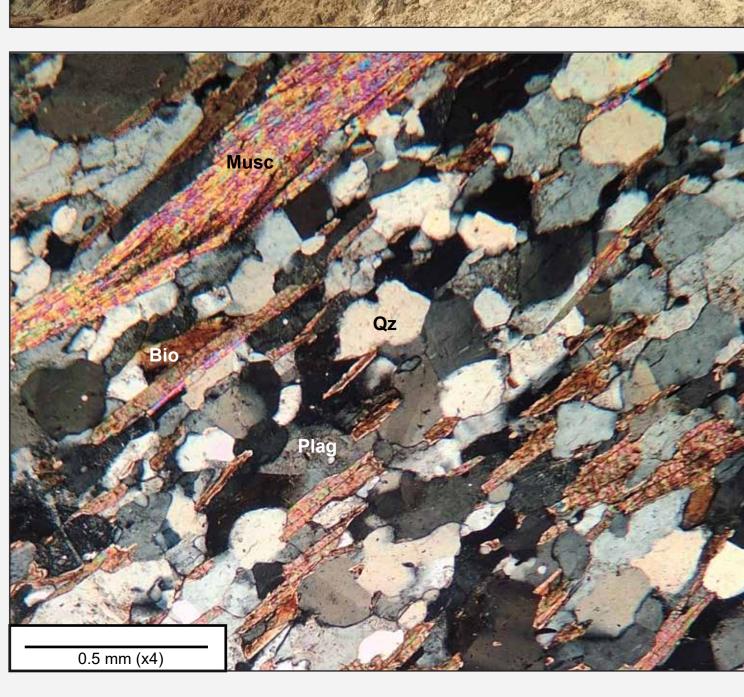
Methods

• O isotopes were measured at the Beijing SHRIMP (Sensitive High Resolution Ion Microprobe) Center, China. U-Pb-Hf isotopes were measured using LA-MC-ICPMS at Frankfurt Isotope and Element Research Center (FIERCE), Goethe-Universität Frankfurt, Germany.





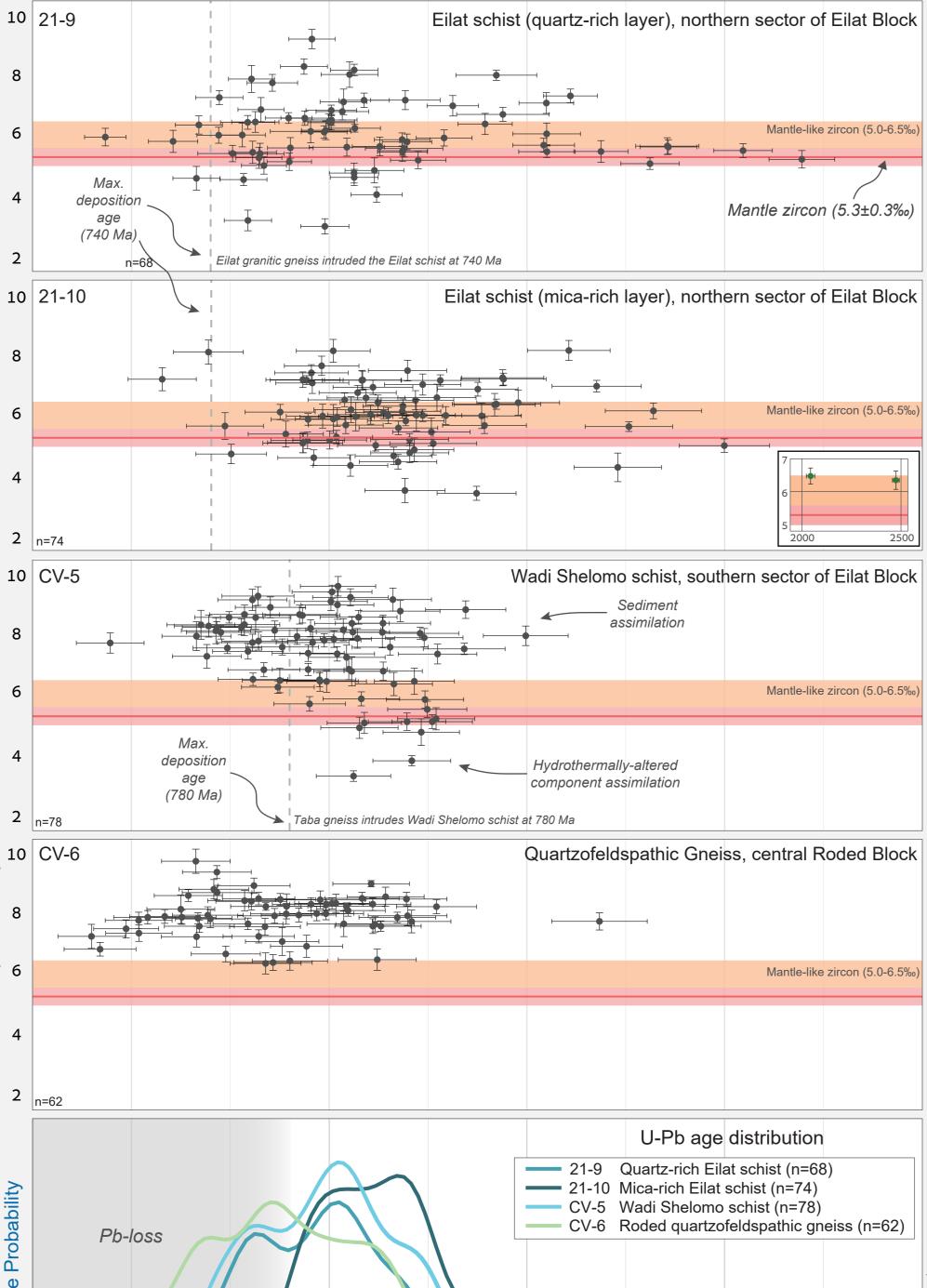




Geochronology and O isotopes

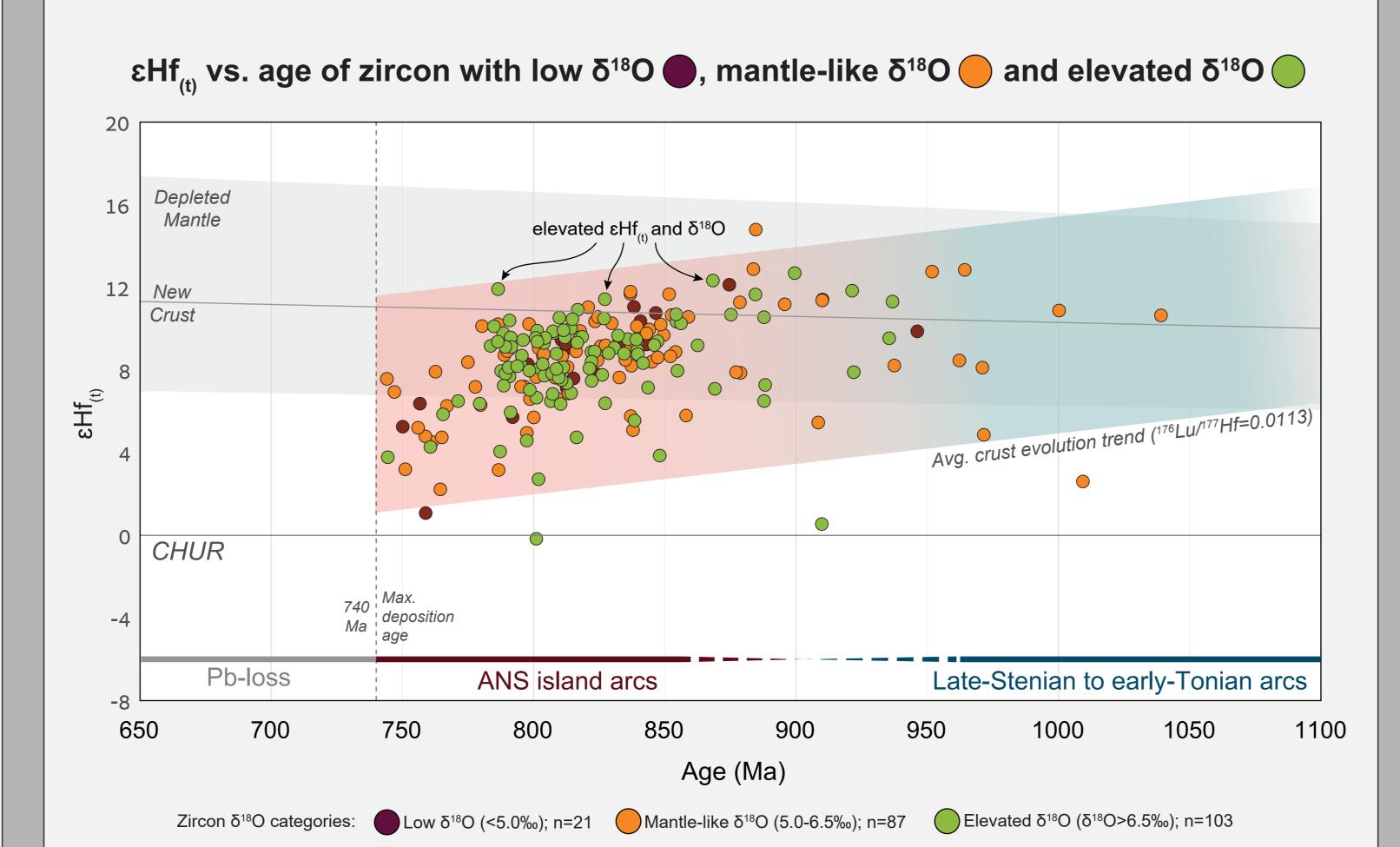
- U-Pb geochronology of detrital zircon places activity peaking between 850-750 Ma.
- 9.6±0.3%
- 34% of the analysed zircons (n=97) hold a characteristic mantle δ^{18} O value of 5.3±0.3‰, or a mantle-like value of 5.6-6.5%. The rest of the zircons have elevated δ^{18} O values (>6.5%) or low δ^{18} O values (<5.0%).
- Zircon with elevated δ¹⁸O values indicate of ¹⁸O-rich components like sediments, whereas zircon with low δ¹⁸O values reflect assimilation of hydrothermally-altered components like fluids or hydrous melts derived from deeper crustal levels of the subducting lithosphere.
- Elevated δ¹8O values as early as ~940 Ma indicate significant melt assimilation of supracrustal components during most of the island arcs magmatic activity period.
- Late-Stenian to early-Tonian zircon ages predate the common activity period of island arcs in the northen Arabian-Nubian Shield. Zircons of this age have strictly mantle-like δ¹⁸O values, indicating uncontaminated magmatism. These ages may represent a primary stage of island arc formation.

δ¹8O vs. age of detrital zircon in Eilat metasediments



Recycling and assimilation of supracrustal components

• εHf_(t) values in the entire detrital zircon population are mostly positive, generally ranging between +4 and +12. These values reaffirm the principally juvenile island arc magmatism that persisted in the Tonian and support the incorporation of only a minor amount of old crust.

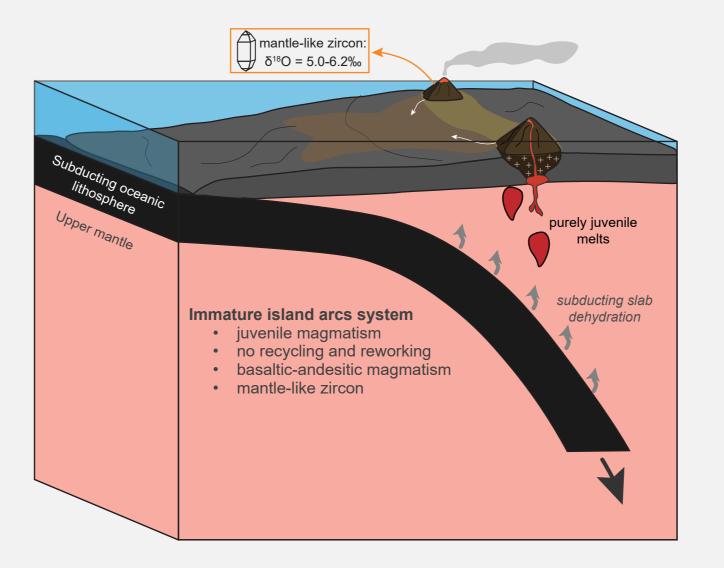


- Zircons with elevated δ¹⁸O and positive εHf_(t) reflect assimilation of then-young ¹⁸O-rich sediments with a juvenile Hf signature shortly after the formation of their protolith, implying the island arc recycled its own sedimentary products soon after formation.
- Zircons with low δ¹⁸O and relatively low εHf_(t) values may resemble melts that assimilated both fluids/hydrous melts derived from deeper crustal levels of the subducting lithosphere (delivering ¹⁸O-depleted signature), and sediments (delivering slightly mature Hf signature).

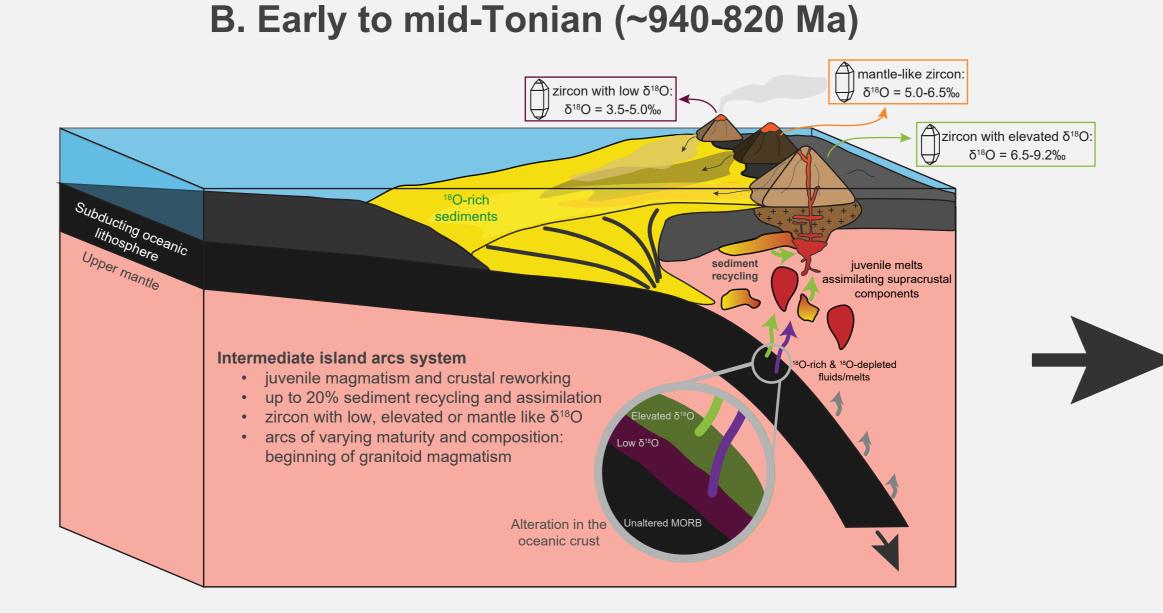
A model for late-Stenian to early-Tonian island arcs evolution in the northernmost Arabian-Nubian Shield

A. Late-Stenian to early-Tonian (~1040-940 Ma)

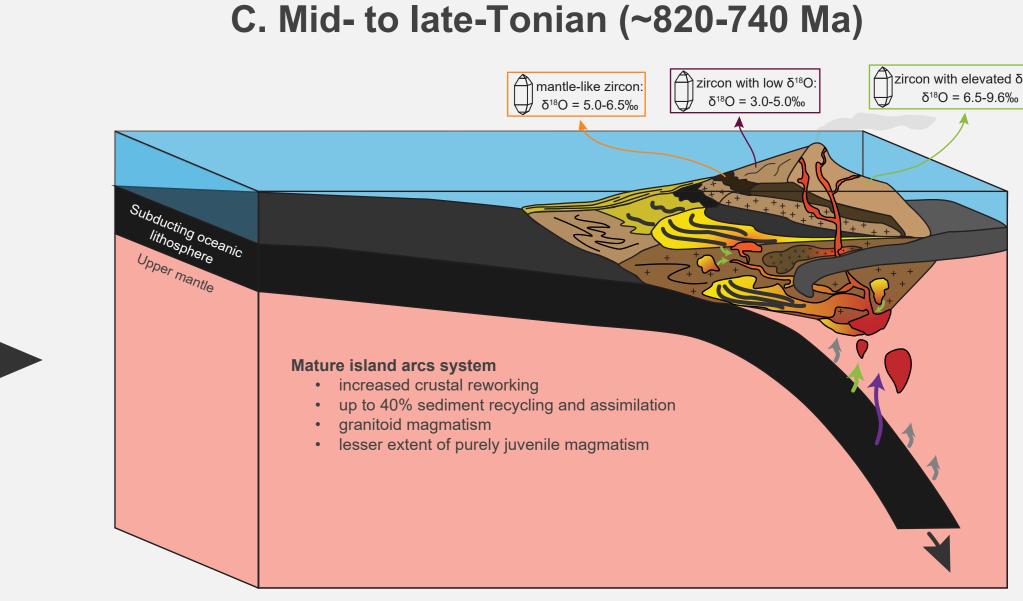
hydrothermally-altered subducting slab fluids/hydrous melts.



 Eilat schist zircons dated to 1040-940 Ma are characterized by mantle-like $\delta^{18}O$ and generally high $\epsilon Hf_{(t)}$ values that indicate juvenile and uncontaminated island arc activity. Their proportion is relatively small in accordance with the immature stage of the arc.



■ From 940 Ma, δ¹8O values increase and εHf_{tt}, values slightly decrease, suggesting reworking and recycling of young, arc-derived sediments. The Roded quartzofeldspathic gneiss of 850-785 Ma indicates that granitoid magmatism coexisted with andesitic magmatism, represented by Eilat schist. Elevated $\delta^{18}O$ values in the quartzofeldspathic gneiss imply that the formation of its granitoid protolith was promoted by crustal recycling.



 Post-820 Ma zircons with abundant elevated δ¹8O values and slightly lower εHf_(t) values point to an increase in the degree of crustal reworking and sediment assimilation, alongside a relative decrease in the contribution of purely mantle-derived melts. This stage corresponds to a more mature arc, perhaps associated with arc accretion.

Key findings

- Island arcs evolution is demonstrated by coupling U-Pb-Hf-O isotopes in detrital zircons from Eilat metasediments.
- Positive εHf_m values of zircons with mantle δ¹8O values decline with age, suggesting that juvenile magmatism was accompanied by reworking of the juvenile island arc crust. • Zircons with elevated δ¹⁸O and positive εHf_{tt} values indicate assimilation of sediments eroded from the island arcs themselves rather than reworking of an older terrain.
- The lack of zircon with negative εHf_{tt} values and pre-Stenian ages reflect a minor contribution of older crust, suggesting that the island arcs terrain evolved in an oceanic realm, far from any older continental margin.
- Detrital zircon with elevated δ¹8O values that were derived from a granitoid protolith imply that crustal recycling could be a driving fource behind crust maturation.
- These results imply that successive reworking of arc terranes and the incorporation of supracrustal components played a fundamental role in the evolution of the juvenile island arcs in the northernmost Arabian-Nubian Shield.



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abstract:

References

(Kernel density estimation bandwidth = 12)

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