Does redistribution of rare earth elements in turbidites of the Appalachian foreland basin compromise provenance information?

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Introduction

The turbidites of the Middle Ordovician Austin Glen Member of the Normanskill Formation are part of the allochthonous sequence in the Appalachian foreland basin. They were deposited during the Taconian Orogeny in front of the accretionary prism about 470 Ma years ago. One major unresolved question in Appalachian geology is what collided with the Laurentian continent during the Taconian Orogeny. Provenance analysis of the Austin Glen may help to resolve this question about the nature of the colliding terrane.

Rare earth elements are considered to be immobile during weathering and diagenesis, and are therefore useful tools to determine the provenance of sedimentary rocks (McCulloch and Wasserburg, 1978; Taylor and McLennan, 1985). *REE* patterns of typical crustal rocks are *LREE*-enriched with negative Eu-anomalies and relatively flat *HREE*. *REE* characteristics of the provenance are thought to be transferred without fractionation from the source areas into sedimentary rocks. Variations in *REE* pattern shapes are mostly found in active tectonic settings where a variety of *REE* patterns can be observed reflecting the composition and/or maturity of the provenance. Nd isotopes allow the calculation of average mantle extraction age of the source(s) of sedimentary rocks. Using *REE* patterns and Nd-isotope data together allows us to evaluate the provenance of a sedimentary rock and also, to evaluate *REE* behavior during weathering and diagenesis and possibly to determine the age of any observed *REE* mobility (Sm–Nd fractionation).

Sampling

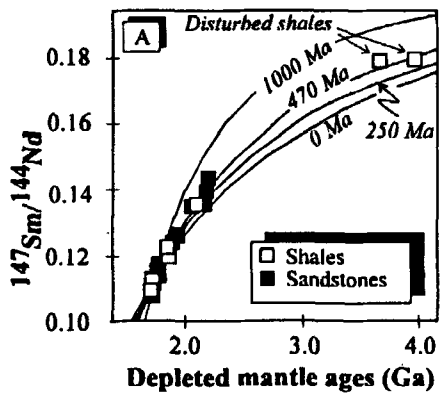
A total of 18 sandstones and 7 shales were collected and analyzed for *REE* abundances and Nd isotopic compositions. Thirteen samples were collected from a continuous section west of Poughkeepsie, NY, in order to determine whether there is a change in *REE* pattern shape and Nd isotopic composition related to stratigraphy. Eleven more samples were collected in the same thrust slice up to 160km to the north, and one sandstone was collected about 60 km southwest of Poughkeepsie. The stratigraphic positions of these 12 samples relative to the samples from Poughkeepsie are not known.

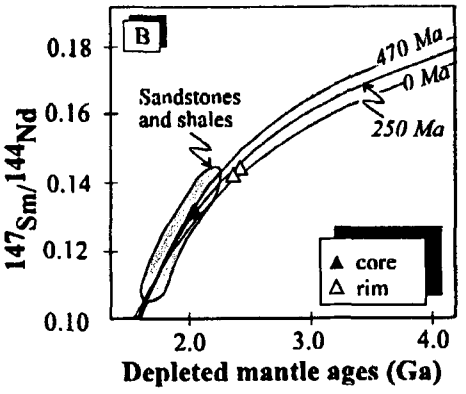
Analytical methods

The samples were crushed to pea-size and powdered in an agate shatter box. The sandstone collected southwest of Poughkeepsie showed a tanned weathered rim of about 3cm surrounding a gray unweathered core. The rim and core were separated and analyzed separately. Samples were fused with lithium metaborate flux at 1100°C for 15 to 20 minutes. The *REE* were separated as a group from other elements on cation exchange resin (AG 50X8) columns using a combination of HCl and HNO_3. Earlier analyzed samples were spiked with ^{145}Nd-enriched spike for *REE* abundances and Nd isotopic compositions were measured on separate splits. Later analyzed samples were aliquoted prior to spiking with ^{145}Nd. The total analytical error on *REE* abundances is less than 1%, and for Nd isotopic compositions about ± 0.2 ε-units.

Results and discussion

REE abundances and shapes of patterns of 23 samples are typical for upper crustal rocks, exhibiting *LREE*-enrichment, negative Eu-anomalies and relatively flat *HREE* patterns. Two shales collected in the continuous section exhibit quite different *REE* abundances and pattern shapes. The *REE* abundances are much lower in these two shales compared to the other samples, and the patterns exhibit a concave upward shape in *LREE* through MREE, with a change in Sm/Nd ratio (0.29 compared to average crustal values of 0.20). ε_{Nd} at 470 Ma is homogeneous with 8.3 ± 0.5 ($n = 25$). Unaltered samples have T_{DM}'s between





1.8 and 1.7 Ga, whereas samples with slight *REE* fractionation have T_{DM}'s of 1.9 to 2.2 Ga. However, the two disturbed shales have T_{DM}'s of 3.65 and 3.95 Ga (Figure A).

The differences in *REE* abundance and pattern shapes of these two disturbed shales could be explained by a change in provenance to a less *LREE*-enriched source, but the similarity of the Nd isotopes of the samples at 470 Ma requires Sm-Nd fractionation at about 470 Ma. Sm–Nd fractionation would also explain the old TDMÆs of the disturbed shales. We favour a process of fractionation during early diagenesis, similar to the one described by Milodowski and Zalasiewicz (1991). Figure A shows calculated trends for rocks with TDMÆs of 1.8 Ga that experienced Sm-Nd fractionation at 1000, 470, 250 and 0 Ma. The two shales plot closest to a fractionation trend calculated for 470 Ma. We argue that the *REE* were fractionated during diagenesis. Perhaps the Nd isotopic system was also homogenized.

The analyses of the two fractions of the sandstone that was split into rim and core also show *REE* redistribution. Figure B shows that the unweathered core is similar to the other samples of the Austin Glen that experienced only slight fractionation of Sm and Nd, whereas the rim plots closer to the fractionation trend calculated for 0 Ma. The rim has similar *REE* abundances and pattern shape to the core, but its Sm/Nd ratio is 0.2468 (n=4) compared to 0.2192 (n=3) for the core. The present day ε_{Nd} of the rim is within analytical uncertainty of ε_{Nd} present day for the other samples. However, ε_{Nd} at 470 Ma for the rim is -9.4 ± 0.2, which is outside analytical uncertainty of -8.4 ± 0.2 for the core, which is the same as the ε_{Nd} of the other samples at 470 Ma. The T_{DM} for the rim is 2.4 Ga, whereas the T_{DM} of the core is 2.0 Ga. These data suggest that the fractionation of Sm and Nd happened during recent weathering.

This study has shown that *REE* fractionation can occur during weathering and diagenesis, and indiscriminate use of *REE* patterns and/or Nd isotopes might lead to erroneous conclusions. However, provenance information can be recovered with a sufficiently large database. *REE* patterns and Nd isotopes for the unaltered Austin Glen samples indicate a well-mixed upper-crustal source or sources with T_{DM}'s of about 1.8 Ga, whereas altered samples give erroneous T_{DM}'s of 2.0 to 3.95 Ga.

References

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