The Rb-Sr method

Based on the decay reaction:

\[ ^{87}_{37}Rb \rightarrow ^{87}_{38}Sr + \beta^- \]

with a half-life

\[ T_{1/2} = 48.8 \text{ Ga} \]

We write the geochronometry equation in terms of the ratio \(^{87}Sr/^{86}Sr\) because ratios are more accurately determined by mass spectrometry

\[
\frac{^{87}Sr}{^{86}Sr} = \left( \frac{^{87}Sr}{^{86}Sr} \right)_0 + \frac{^{87}Rb}{^{86}Sr} (e^{\lambda t} - 1)
\]
The Rb-Sr method is commonly used to date Rb-rich minerals such as muscovite, biotite and K-feldspar; these same minerals usually do not incorporate much Sr at the time of their formation (Goldschmidt’s rules).

We usually use the isochron method to determine the age and initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratio of a suite of rocks.
Rb-Sr System

Number of protons

Number of neutrons

Isotope abundance

Sample A  Sample B  Sample C

$T_{1/2} = 4.8 \times 10^{10}$ years
Rb-Sr isochron diagram for a series of rock samples formed at the same time

\((^{87}\text{Sr} / ^{86}\text{Sr})_0 = 0.7114\)

Slope = \((e^{\lambda t} - 1) = 0.04855\)

\(t = 3.34\) B.Y.

\(r^2 = 0.9980\)
Rb-Sr isochron diagram illustrating how the isochron evolves as a function of time. $M_1$ and $M_2$ are cogenetic minerals and $R_1$ and $R_2$ are cogenetic rocks, all with different initial Rb/Sr ratios.
Rechts: Stoffdiffusion durch das Kristallgitter und entlang von Korngrenzen während der Metamorphose

Unten: Verhalten des Rb/Sr-Systems während der Metamorphose
Verhalten des Rb/Sr-Systems während der Metamorphose
Sr isotopic evolution of the Earth

The 87Sr/86Sr ratio of the crust is higher than that of the mantle due to the preferential partitioning of Rb into the crust relative to Sr.

Continental crust: 32-78 ppm Rb, 260-333 ppm Sr
Depleted Mantle: 0.6 ppm Rb, 19.9 ppm Sr
Sr isotopes as tracer of rock origin

**Undifferentiated earth**

- $^{87}\text{Sr}/^{86}\text{Sr} = 0.699$ at 4.5 Ma
- $^{87}\text{Sr}/^{86}\text{Sr} = 0.7014$ at 2.7 Ma

**Crust at 1.0 Ma**

- $^{87}\text{Sr}/^{86}\text{Sr} = 0.7140$

**Mantle at 1.0 Ma**

- $^{87}\text{Sr}/^{86}\text{Sr} = 0.7034$

**Crust and mantle differentiate at 2.7 Ma**

**Present day rock with**

- $(^{87}\text{Sr}/^{86}\text{Sr})_0 = 0.7140$
- $(^{87}\text{Sr}/^{86}\text{Sr})_{\text{crust}} = 0.7211$
- $(^{87}\text{Sr}/^{86}\text{Sr})_{\text{mantle}} = 0.7045$

**Rocks form from crust at 1.0 Ma**

**Rocks form from mantle at 1.0 Ma**
Sr isotope composition of the oceans is determined by the relative contributions of Sr from river waters and hydrothermal sources.

* river water
  \[ \frac{^{87}Sr}{^{86}Sr} = 0.711 \]

* hydrothermal fluids
  \[ \frac{^{87}Sr}{^{86}Sr} = 0.703 \]

* sea water
  \[ \frac{^{87}Sr}{^{86}Sr} = 0.709 \]

* carbonate shells
  \[ \frac{^{87}Sr}{^{86}Sr} = 0.709 \]
The evolution of $^{87}\text{Sr}/^{86}\text{Sr}$ with time in the continental crust and mantle

$(87\text{Sr}/86\text{Sr})_0$ ratios can be used as a tracer to determine if a magma evolved from the mantle or if crust was involved.

For mantle-derived rocks: $(87\text{Sr}/86\text{Sr})_0 \approx 0.700-0.706$

For crustal involvement: $(87\text{Sr}/86\text{Sr})_0 \approx 0.705-0.740$