Radiometric Dating:
Isotope Geochronology and Age Determination

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Abstract

This report presents a comprehensive analysis of radiometric dating methods. We examine radioactive decay kinetics, implement isochron dating for Rb-Sr and U-Pb systems, analyze concordia-discordia relationships, calculate closure temperatures, and demonstrate carbon-14 dating for recent samples. All computations use PythonTeX for reproducibility.

Contents

Chapter 1

Introduction

Radiometric dating determines absolute ages of geological materials using radioactive decay:

$$N(t) = N_0 e^{-\lambda t} \tag{1.1}$$

where N_0 is the initial number of parent atoms, λ is the decay constant, and t is time.

1.1 Decay Constant and Half-Life

The relationship between decay constant and half-life:

$$\lambda = \frac{\ln 2}{t_{1/2}} \tag{1.2}$$

1.2 Age Equation

From the parent-daughter relationship:

$$D = D_0 + N(e^{\lambda t} - 1) \tag{1.3}$$
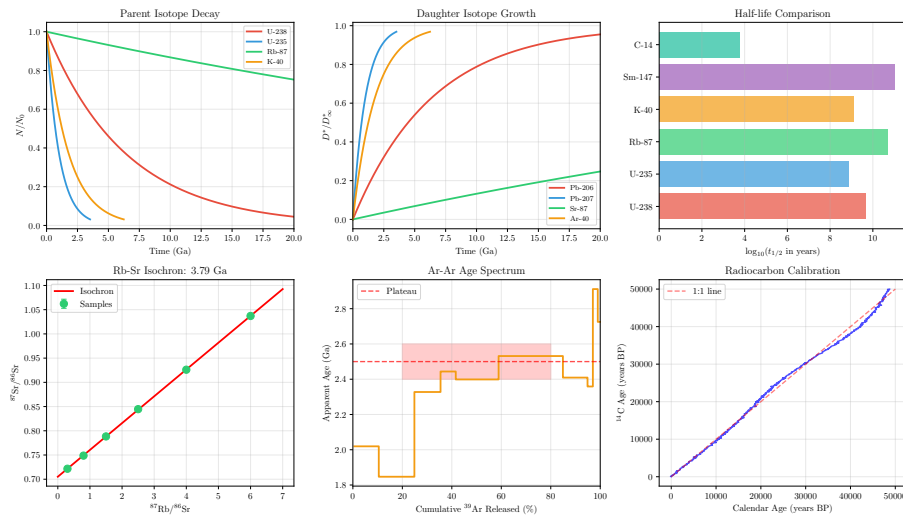
Chapter 2

Radioactive Decay Kinetics

Figure 2.1: Radioactive decay: (a) parent decay curves, (b) daughter growth, (c) half-life comparison, (d) Rb-Sr isochron, (e) Ar-Ar spectrum, (f) C-14 calibration.

Chapter 3

U-Pb Concordia Dating

3.1 Concordia Equation

The U-Pb concordia curve represents concordant ages:

$$\frac{^{206}\mathrm{Pb}^*}{^{238}\mathrm{U}} = e^{\lambda_{238}t} - 1 \tag{3.1}$$

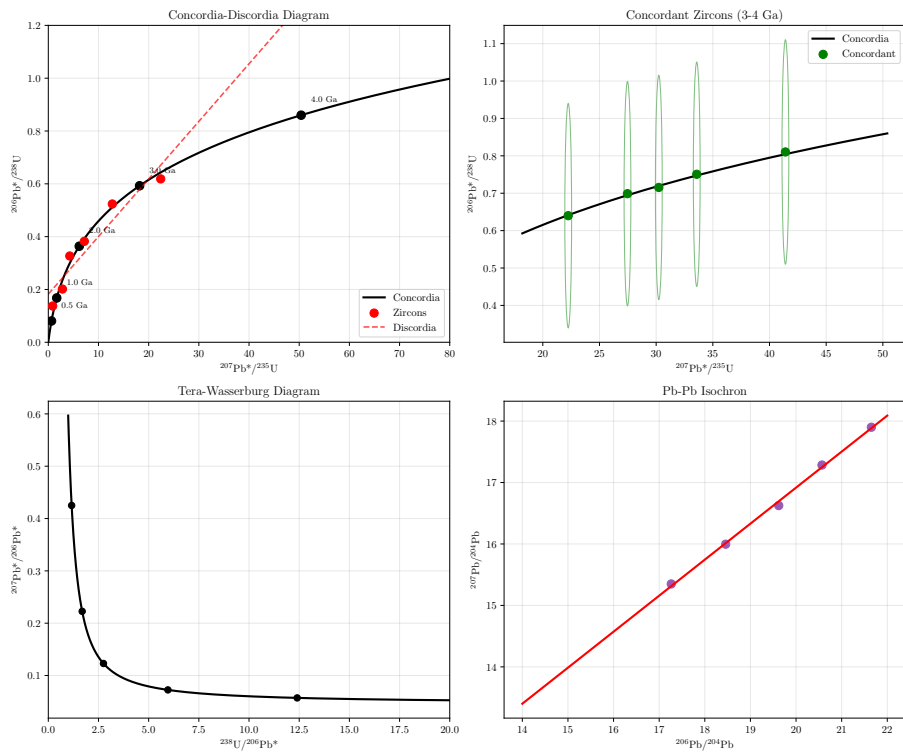$$\frac{^{207}\mathrm{Pb}^*}{^{235}\mathrm{U}} = e^{\lambda_{235}t} - 1 \tag{3.2}$$

Figure 3.1: U-Pb dating: (a) concordia-discordia, (b) concordant zircons, (c) Tera-Wasserburg, (d) Pb-Pb isochron.

Chapter 4

Closure Temperature

4.1 Dodson Equation

The closure temperature T_c depends on diffusion parameters:

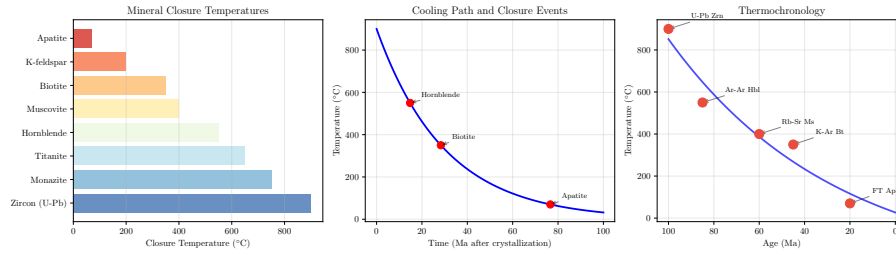$$T_c = \frac{E_a/R}{\ln\left(\frac{ART_c^2 D_0/a^2}{E_a \cdot dT/dt}\right)} \tag{4.1}$$

Figure 4.1: Closure temperature: (a) mineral comparison, (b) cooling path, (c) multi-system thermochronology.

Chapter 5

Numerical Results

Table 5.1: Radiometric dating results

Parameter	Value	Units
??	??	??
??	??	??
??	??	??
??	??	??
??	??	??
??	??	??

Chapter 6

Conclusions

1. Isochron dating provides both age and initial ratios

2. U-Pb concordia reveals open-system behavior

3. Multiple isotope systems enable cross-validation

4. Closure temperature controls age interpretation

5. Thermochronology constrains cooling histories

6. Radiocarbon requires calibration for calendar ages