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Deep Time, Data, and Doubt: The Evolving Role of Geochemistry in Undergraduate Education

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Geochemistry is an essential, distinctive discipline in geoscience education, training students to analyze processes across vast scales of space, time, and uncertainty. At its core, geology introduces students to “deep time” — a temporal framework that fundamentally reshapes how they interpret environmental change. Geochemical tools make deep time tangible. Isotopic systems, elemental cycles, and mass balance approaches allow students to reconstruct processes that operate over millions to billions of years while connecting them directly to modern challenges such as climate change, water quality, and energy needs.

Geochemistry is inherently an exercise in reasoning through ambiguity. A single isotopic signature or elemental pattern may admit multiple plausible interpretations, each with different process-based backstories. Teaching geochemistry, therefore, requires explicit engagement with the method of multiple working hypotheses. Students must weigh competing models, evaluate assumptions, quantify uncertainty, and distinguish signal from noise. These habits of mind extend far beyond disciplinary content; they cultivate transferable critical thinking skills essential for navigating complex scientific and societal debates.

The emergence of AI adds a new dimension to geoscience education. AI tools can synthesize literature, assist with data processing, and accelerate pattern recognition, but they also risk obscuring the interpretive reasoning that underpins geochemical inference. After more than a quarter century teaching biogeochemistry and hydrogeology I have begun integrating these tools into my undergraduate classroom. The hope is that instead of replacing geochemical reasoning, AI can be leveraged to expose students more quickly to authentic, messy datasets—freeing time for higher-order analysis and hypothesis testing. The reality may be quite different, and is a pedagogic skill set that is quite different from the old ways of doing things. Students’ reactions to using it implicitly in the classroom also varies widely – from those who strongly wish to refrain to those who accept it uncritically.

With some lessons learned, geochemistry instruction can equip students not only to address pressing environmental challenges, but also to become scientifically literate citizens capable of evaluating evidence in an increasingly data-saturated world.