Geophysical Research Abstracts
Vol. 12, EGU2010-1482, 2010
EGU General Assembly 2010

EARTHTIME: Teaching geochronology to high school students

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The authors taught an educational module developed as part of the EARTHTIME (www.earth-time.org) outreach initiative to 215 high school students from a Massachusetts (USA) High School as part of an "out-of-school" field trip. The workshop focuses on uranium-lead (U-Pb) dating of zircons and its application to solving a geological problem. The theme of our 2.5-hour module is the timing of the K-T boundary and a discussion of how geochronology can be used to evaluate the two main hypotheses for the cause of the concurrent extinction—the Chicxlub impact and the massive eruption of the Deccan Traps. Activities are divided into three parts:

In the first part, the instructors lead hands-on activities demonstrating how rock samples are processed to isolate minerals by their physical properties. Students use different techniques, such as magnetic separation, density separation using non-toxic heavy liquids, and mineral identification with a microscope. We cover all the steps from sampling an outcrop to determining a final age. Students also discuss geologic features relevant to the K-T boundary problem and get the chance to examine basalts, impact melts and meteorites.

In the second part, we use a curriculum developed for and available on the EARTHTIME website (http://www.earth-time.org/Lesson_Plan.pdf). The curriculum teaches the science behind uranium-lead dating using tables, graphs, and a geochronology kit. In this module, the students start by exploring the concepts of half-life and exponential decay and graphically solving the isotopic decay equation. Manipulating groups of double-sided chips labeled with U and Pb isotopes reinforces the concept that an age determination depends on the Pb/U ratio, not the absolute number of atoms present. Next, the technique's accuracy despite loss of parent and daughter atoms during analysis, as well as the use of isotopic ratios rather than absolute abundances, is explained with an activity on isotope dilution. Here the students determine the number of beads in a large bucket without counting them all by adding a precisely known number of "tracer" beads and averaging ratios from several small samples of the mixture. The (pre-counted) unknown quantity of beads represents the isotopic composition of zircon from four samples—the Deccan Trap basalts, the Chicxulub impact melt, and ash layers above and below the K-T boundary —and the students' measurements are used in the final part of the module. An introduction to statistical inference from small samples can also be added to this exercise. After this, the chemistry and physics behind geochemical laboratory techniques, ion exchange chromatography and isotope ratio measurements using a mass spectrometer, are explained using models, movies, posters, and analogies to familiar physics.

In the final part, students engage in a summary exercise where they apply what they have learned to test the two competing hypotheses. Using the dates they calculated with isotope dilution and a graphical solution to the decay equation, they determine if the Chicxulub impact or the Deccan Trap volcanic eruption can explain the K/T boundary mass extinction. They learn the importance of measurement uncertainty in interpreting data and brainstorm how best to resolve this outstanding scientific problem.

Feedback from written evaluations shows that teachers valued the interdisciplinary association of concepts from physics, chemistry and mathematics. Students enjoyed the hands-on exercises that gave them the opportunity to see how rocks can be broken down into mineral separates and individual zircons selected for analysis. The K/T-boundary exercise at the end was appreciated because it demonstrates an exciting application of geochronological methods to popular science.