AUSTRALIAN EARTH SCIENCE EDUCATION

Using Zircon to Determine Earth's Age
Student Worksheet

Why zircon?

Zircon (ZrSiO4) is a silicate mineral that forms within magma. During the formation of zircon, uranium (U) atoms sometimes replace zirconium (Zr) in the crystal structure. However, lead (Pb) is excluded. Over time, some of the uranium decays to lead. By determining the amount and isotopes of uranium and lead in a zircon crystal, U-Pb dating can determine the age of the crystal. Highly sensitive ion probes can be used to obtain U-Pb ratios (and dates) from many areas within one crystal, as shown in Figure 1.

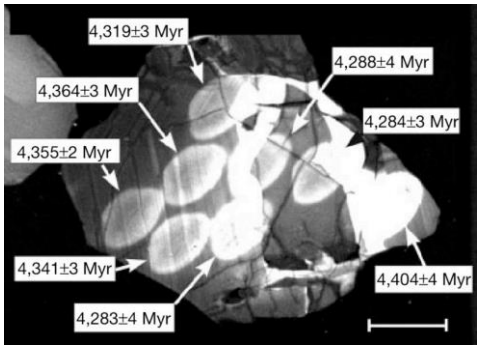

Figure 1. Photomicrograph of the oldest known zircon crystal. Light areas regions of ion probe analysis and the ages from each area are shown. (Image from Wilde SA et al. Nature **409:** 175-178 (2001), reprinted in Chapter 3. Decay Systems and Geochronology II: U and Th. *Isotope Geochemistry*. (2013) Accessed from http://www.geo.cornell.edu/geology/classes/Geo656/656notes13/IsotopeGeochemistry%20Chapter3.pdf)

Uncertainty in the system

The dates in Figure 1 are expressed with an error of three or four million years. The isotopes of uranium that are decaying have extremely long half lives. Uranium-235 has a half life of 700 million years and that of uranium-238 is 4.5 billion years. Thus, there is some uncertainty in the individual measurements.

Within the zircon in Figure 1, there is variation in the age of different areas measured by the ion probe. Zircons form in layers within magma (Figure 2). Subsequent analysis (Ge et al. 2018) indicates that deep and surface probes can provide different ages. The surface layers may be affected by events after crystal formation that lead to a loss of some lead atoms.

In order to deal with uncertainty in measurements, scientists make many measurements of the age of each zircon. They also collect many zircons from the same rock formation. This provides a large data set and greater reliability in measurements.

How old was the first rock?

The first rocks on Earth were weathered, eroded and recycled billions of years ago. However, some zircon crystals from these rocks have persisted in very old areas of Earth's continental crust known as cratons. The oldest zircons of all come from the Jack Hills in Western Australia in an area known as the Yilgarn craton.

The data in the table shows the ages of Jack Hills zircons, as measured by ion probes. You will look at the distribution of zircon ages to determine the age(s) of the original igneous rock.

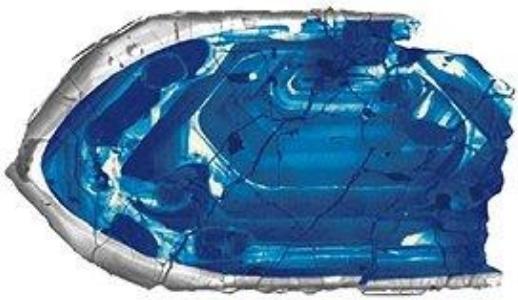

Figure 2. Cathodeluminescence image of a 400 µm Jack Hills zircon crystals reveals its layers (John Valley, University of Wisconsin)

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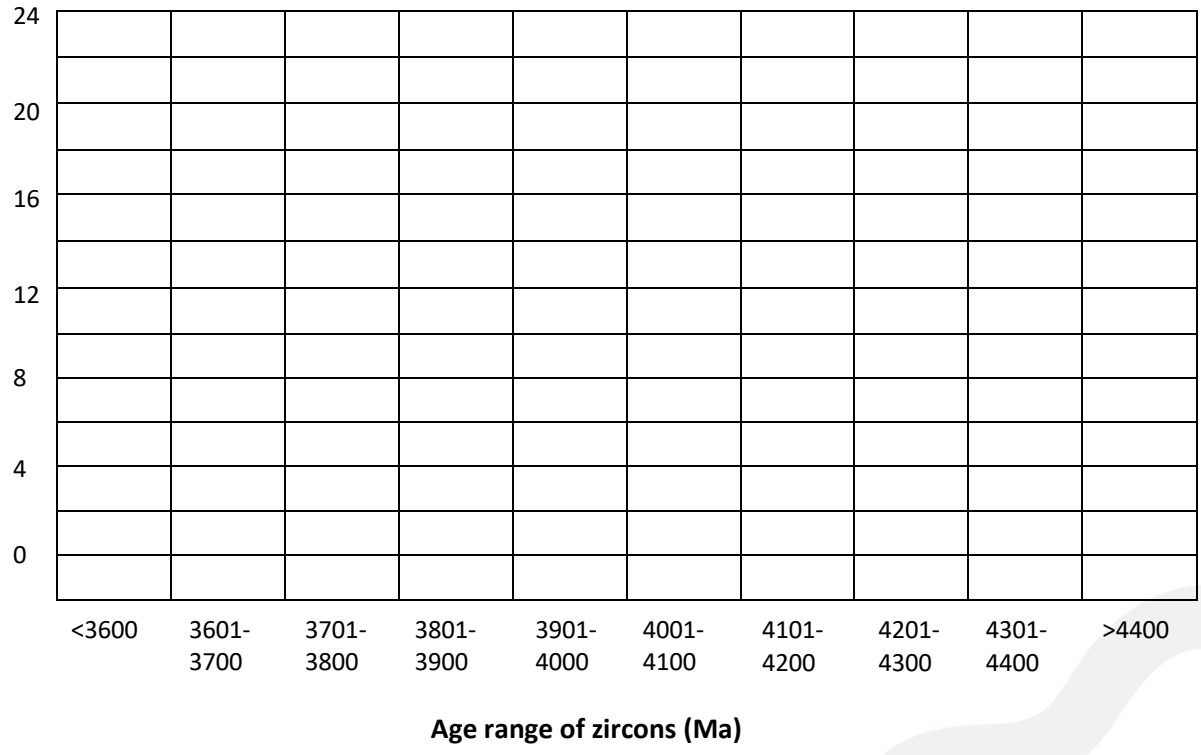
Age of Jack Hills Zircons (subset of data extracted from Belousova et al. 2010)

Age (Ma)					
4102	4142	4027	4024	4146	4094
4008	4097	4213	4133	4077	4086
4114	4131	3941	4169	4049	4030
4137	4029	3966	4146	4057	4027
4085	4112	4321	4232	4174	3571
4056	4077	4100	4042	4100	4199
4119	3913	4102	4048	4196	4225
4013	4120	4081	4041	4304	4248
4159	4089	4192	4048	4272	4327
4130	3922	4113	4153	4158	4165
3963	3920	4230	4160	4244	3999

Questions

1. Plot a histogram of zircon ages



2. Are there any outliers in the data that should be excluded from analysis? Explain.

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3. Do you think the zircons are all from one magma source? Justify your answer based on the histogram. _____

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_____

4. There are 66 ages in your sample, but Belousova's data contained more than 300 zircons. Why would scientists examine that many samples?_____

_____

_____

_____

5. Based on these zircon ages, how old was the oldest original rock?_____

6. Zircons are especially useful because the original crystals do not contain any lead (Pb). Explain why this is important. _____

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7. If you calculated an average of the zircon ages, your calculator or spreadsheet program would provide a long string of numbers after the decimal point. Explain why it may not be reasonable to write them all down as the average._____

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References:

Belousova EA, Kostitsyn YA, Griffin WL, et al. (2010). The growth of the continental crust: Constraints for zircon Hf-isotope data. *Lithos* **119**(3): 457-466. With thanks to the first author for providing the zircon ages.

Cornell University Geology (2013). Chapter 3. Decay Systems and Geochronology II: U and Th. *Isotope Geochemistry*. Accessed from http://www.geo.cornell.edu/geology/classes/Geo656/656notes13/IsotopeGeochemistry%20Chapter3.pdf

Ge R, Wilde SA, Nemchin AA, et al. (2018). A 4463 Ma apparent zircon age from the Jack Hills (Western Australia) resulting from ancient Pb mobilization. *Geology* **46**(4): 303-306. https://doi.org/10.1130/G39894.1

Vermeesch P (2020). Isotope Geology. Part I: Radiometric Geochronology. doi:10.31223/osf.io/sj4ft. Accessed from https://eartharxiv.org/repository/view/1492/