AMHERST COLLEGE

Department of Geology
GEOLOGY 41 - Environmental and Solid Earth Geophysics
Lab 2: Geochronology

EQUIPMENT: **notebook & pen only**

As part of a project to investigate the tectonic history of the New England Appalachians, you have tried to get ages from a single gneissic rock sample from the Pelham Hills. The gneiss is a hornblende and muscovite-bearing banded quartzo-feldspathic rock that may represent either a metamorphosed igneous rock (a granite?) or a metamorphosed sedimentary rock (an arkosic sand/siltstone?, a greywacke?).

You have been able to determine 3 ages from the sample: a U/Pb “concordia” age from zircon and $^{40}Ar/^{39}Ar$ ages from hornblende and muscovite. Analytical data for each of the 3 ages is given below. This data is available as an Excel spreadsheet on the GEOL 41 web page.

U/Pb data

Zircon was separated from the gneiss. Four small (2-5 grain) aliquots of clear (low U/low radiation damage?) prismatic (igneous??) grains were selected and analyzed by mass spectrometry for U and Pb. The U and Pb concentrations (ppm) and the ratios of Pb isotopes ($^{208}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$, $^{206}Pb/^{204}Pb$) are listed below.

aliquot #	U (ppm)	Pb (ppm)	$^{206}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{208}Pb/^{204}Pb$
z1	228.4	23.21	1341.89	93.260	417.990
z2	436.2	57.03	544.604	46.980	269.640
z3	349.1	40.81	468.614	42.634	118.620
z4	542.7	58.82	573.22	47.697	275.262

1) The concentrations of U and Pb are given in mass units (ppm) and need to be converted to the number of atoms of U and Pb in each aliquot. To so this, divide the concentration of U and Pb of each aliquot by the atomic weights of U and Pb. (This method gives you the number of atoms in an arbitrary mass of zircon, but it works because the age equations deal with atom ratios).

2) For each aliquot determine the number of atoms of each of the U (^{235}U, ^{238}U) and P (^{208}Pb, ^{207}Pb, ^{206}Pb, ^{204}Pb) isotopes. For U, this is relatively easy as the ratio of U isotopes in all U is constant. For Pb, this is a bit more complicated because 3 of the Pb isotopes are radiogenic and the abundance of each isotope must be calculated from the analytical data each aliquot. (Do you know how to do this?-If not see Peter)

3) Some of the Pb in your zircon was present when it crystallized. You know that this is the case because there is some non-radiogenic ^{204}Pb in your samples. Use the common Pb isotopic ratios given below to determine the amount of radiogenic ^{207}Pb & ^{206}Pb in each aliquot (i.e., determine the amount of $^{207}Pb^*$ & $^{206}Pb^*$ in each aliquot).
STOP. Be sure to check your results with Peter **BEFORE** proceeding

4) For each aliquot determine the $^{207}Pb^*/^{235}U$ & $^{206}Pb^*/^{238}U$ ratios and using the decay equations for ^{235}U & ^{238}U determine a $^{207}Pb^*/^{235}U$ and $^{206}Pb^*/^{238}U$ age. Are these ages concordant? Are the ages for each aliquot the same?

5) Plot the $^{207}Pb^*/^{235}U$ & $^{206}Pb^*/^{238}U$ ratios for each aliquot on a concordia diagram. Can you now make sense out of your zircon ages?

6) What observations can you make about the tectonic evolution of the Pelham Hills based on your U/Pb zircon and $^{40}Ar/^{39}Ar$ ages?

$^{40}Ar/^{39}Ar$ data

Aliquots of hornblende and muscovite were separated from the gneiss and irradiated along with a biotite standard. Following irradiation, each aliquot was incrementally heated to release Ar and the ratios of $^{39}Ar/^{40}Ar$ and $^{36}Ar/^{40}Ar$ for each heating step of each aliquot was measured.
The ratios of $^{39}Ar/^{40}Ar$ and $^{36}Ar/^{40}Ar$ are measured during each heating step are listed below. These ratios have been corrected for the production of ^{36}Ar, ^{39}Ar and ^{39}Ar in the reactor by competing nuclear reactions involving isotopes of Ca and Cl.

	T(°C) of heating step	**%^{39}Ar released this step**	**$^{39}Ar/^{40}Ar$**	**$^{36}Ar/^{40}Ar$**
56.7 Ma biotite standard	fusion	100	0.4122	0.00001
hornblende				
	600	12	0.0408	0.00041
	700	17	0.0514	0.00046
	800	28	0.0557	0.00027
	900	18	0.0586	0.00007
	1000	15	0.0573	0.00009
	fusion	10	0.0531	0.00033
muscovite				
	500	9	0.064	0.00002
	600	23	0.0651	0.00001
	700	14	0.0643	0.00003
	800	28	0.0644	0.00003
	fusion	26	0.0629	0.00017

These data can be downloaded as an Excel spreadsheet from the course web page

1) In order to determine the $^{40}Ar/^{39}Ar$ ages of your samples, you must know the ratio $^{40}Ar^{*}/^{39}Ar$, the ratio of **radiogenic** ^{40}Ar to ^{39}Ar. To do this, you must correct your measured ratios of $^{40}Ar/^{39}Ar$ for any Ar the was introduced during sample preparation. You know that some Ar **must** have been introduced into each aliquot that was analyzed because there is some ^{36}Ar in each aliquot. Assume that the source of ^{36}Ar is modern atmosphere ($^{40}Ar/^{36}Ar = 295.5$) and **correct** each of the measured values of $^{40}Ar/^{39}Ar$ for ^{40}Ar that was introduced during sample preparation and determine $^{40}Ar^{*}/^{39}Ar$ for each aliquot.

2) Determine the neutron flux parameter J for your analyses using the Ar isotopic ratios collected from the 56.7 Ma biotite standard.

3) Determine an $^{40}Ar/^{39}Ar$ age for each of the heating steps for the two samples (muscovite and hornblende). Also determine a total gas $^{40}Ar/^{39}Ar$ age for both samples.

4) Using the ages determined above, plot an Ar age spectrum (apparent age vs. cumulative percent of Ar) for each of the 2 samples.

5) Assuming a ±3 Ma error in the age of each release step, do your ages represent a plateau?

The following constants and equations may prove useful

$(^{40}Ar/^{36}Ar)_{atm}$	=	295.5
$^{235}U/^{238}U$	=	0.00725670
common Pb		
$^{206}Pb/^{204}Pb$	=	17.915
$^{207}Pb/^{204}Pb$	=	15.583
$\lambda(^{40}K_\beta)$	=	4.962×10^{-10} /yr (decay to ^{40}Ca)
$\lambda(^{40}K_e$	=	0.581×10^{-10} /yr (decay to ^{40}Ar)
$\lambda(^{40}K)$	=	$\lambda(^{40}K_\beta)+\lambda(^{40}K_e)$
$\lambda(^{235}U)$	=	9.8485×10^{-10} /yr
$\lambda(^{238}U)$	=	1.55125×10^{-10} /yr
$^{40}Ar^{*}/^{39}Ar$	=	$(^{40}Ar/^{39}Ar)_{measured}-(^{40}Ar/^{36}Ar)_{atm}(^{36}Ar/^{39}Ar)_{measured}$
$^{40}Ar^{*}/^{39}Ar$	=	$[\exp(\lambda t) -1] / J$
$^{40}Ar^{*}$	=	$^{40}K\ \lambda_e / \lambda\ [\exp(\lambda t) -1]$
$^{206}Pb^{*}$	=	$^{238}U [\exp(\lambda_{238} t) -1]$
$^{207}Pb^{*}$	=	$^{235}U [\exp(\lambda_{235} t) -1]$
$T_{closure}$ (zircon)	>	600 °C
$T_{closure}$ (hornblende)	=	550 °C
$T_{closure}$ (muscovite)	=	400 °C
$T_{closure}$ (biotite)	=	350 °C

atomic weights

Ar	39.948	Pb	206.18
K	39.0983	U	238.02891
Ca	40.078		