EarthChem Workshop on Geochronology for Ar-Ar

University of Kansas, Lawrence, Kansas 66045
May 2, 2008, 8:30am to 5:00 pm

Report compiled by Doug Walker, Paul Renne, Anthony Koppers, Kip Hodges

Participants:
Doug Walker, Matt Heizler, Al Deino, Anthony Koppers, Paul Renne, Kip Hodges (part)

Background
EarthChem is a community driven project to facilitate the compilation and dissemination of geochemical data of all types. The project is active at building a home for future data contributions by working with authors, societies, and publishers as well as government organizations. In addition, the EarthChem project responds to community needs to facilitate compiling and serving data.

A recently identified community need is in the area of geochronology. At the GeoEarthScope town hall meeting held in association with the 2006 GSA National Meeting in Philadelphia, attendees discussed the necessity of a home for geochronology and thermochronology data collected by that project. Consensus opinion of attendees and organizers was that EarthChem should be the group to provide management for data collected in association with GeoEarthScope, storing and serving geochronological data submitted by participating facilities. Such a management system would be useful to other workers. EARTHTIME, for example, strongly endorses EarthChem's leadership in this regard and will work to encourage members to contribute data. This emphasis was endorsed by the EarthChem advisory board at its 2006 annual meeting.

To move this effort forward, several small workshops were held in 2007 and 2008 to ensure that the proper standards for data and metadata reporting are enforced. To this end, EarthChem worked with experts in the field of U-Pb geochronology (who are also connected with the EARTHTIME effort) in an April 2007 meeting, and experts at (U-Th)/He geochronology/thermochronology at a May 2008 meeting. Meetings for Ar-Ar and cosmogenic nuclide dating were held in April and May 2008, respectively, with experts connected with the EARTHTIME and CRONUS efforts, respectively. This report gives the results of the Ar-Ar workshop.

Goals
Goals of the meeting were to address important issues for creating a home for data related to Ar-Ar dating.

a. Establish reporting requirements including metadata and classes of measured values.
b. Identify and evaluate methods of data entry and output that will work for the community.
c. List the important requirements of a geochronology website.
d. Plan approaches and actions for moving forward with the effort.

Workshop Summary

The workshop group focused most of its effort on identifying the important items that must be reported for Ar-Ar geochronology and thermochronology results. This is presented as a large table at the end of the report. This is a relatively mature community, and they have discussed previously data reporting requirements through the EARTHTIME project. It is clear that the Ar-Ar method is applicable to both geochronology and thermochronology. For simplicity, we refer to geochronological applications below, recognizing the added aspect of thermochronology.

The group addressed the need for an easy path for data entry. Although contributors to a database can enter parameters directly into a spreadsheet or web-based form, the group considered that the most appropriate route would be to take output directly from data reduction programs/spreadsheets. The majority of this community employs two principal data reduction programs to generate data and age interpretations – ArArCalc (written and maintained by Koppers) and Mass Spec (written and maintained by Deino). This means that the reduction infrastructure that incorporates extensive data and metadata already exists for the Ar-Ar method. The group decided that building a set of web services based on these reduction programs was the most direct and easy path to database development. The general *approaches* and *next steps* to creation of a geochronology database for Ar-Ar are described below.

Approaches

A basic recommendation of data reporting is that there should be an IGSN for each sample and subsample (mineral separate, aliquot, etc.). To this end, the data entry system will ask for the IGSN identifier. This can be done with a link to the SESAR site during data entry/upload if the IGSN is not present. If present, the IGSN will be verified against the database. It is important that users be able to establish their own IGSN for host samples in the field.

Because mature reduction programs exist for the Ar-Ar method, the group decided that harvesting data directly from these reduction programs was the most direct and easy path to database development. Harvesting would be done in the programs themselves gathering data and metadata required for incorporation into the geochronology database. The programs would provide a simple user interface for upload that would interact with the database using a set of web services. Basic to the interface would be getting or verifying an IGSN for each sample/subsample.

The database itself will be built on XML using a schema that preserves the critical data and metadata (see attached table). This will allow other parties to access the data through the XML if needed; the creation of the XML schema is critical to maintaining interoperability. The group understands that the Ar-Ar geochronology database will be one of several such geochronology systems. The interoperability of these systems is important for future inquiry. The use of an IGSN identifier will ensure that samples can be tied together in the future. For example, the participants considered the potential value

in comparing high- and low-temperature chronometer ages especially appealing, in light of the potential to make powerful new interpretations of locations and regions.

Lastly, the user interface needs to allow complex queries and tailor the output of such queries to the need of the user. For this reason, the interface must allow for simple display and download for casual/non-geochronologist users (probably the vast majority) and complete and rich interactions for experts.

Next Steps

Considering the approaches listed above, the participants recommended the following next steps to move the process of creating a geochronology database. We anticipate that these steps will be done over the next 6 to 24 months.

1) Prepare and circulate the report of this workshop. The report will be posted on the EarthChem, KU and EARTHTIME websites as well as being emailed to a list of critical data providers. This will allow for community comments on the critical reporting items included in the attached table.

2) Start developing the XML schema. This will be done by taking the list of critical items (see table) combined with some sample data to create a structure. The schema should allow for efficient search and retrieval. The schema will be normalized to the extent needed by the amount and complexity of potential data. Exploration of existing schemas (such as OGC and GeoSciML) will be done to further foster interoperability. Jason Ash and Eileen Jones (EarthChem programmers) will work on this effort in conjunction with Al Deino and Anthony Koppers, who will provide reduction program output.

3) Prototype a (U-Th)/He geochronology website. This may be stand-alone or, more likely, be part of an integrated geochronology website. Many components may be built upon existing components of the EarthChem site. Eileen Jones and Jason Ash will start this.

4) Integrate programs from both individual users and the Mineralogical Society of America website (http://www.minsocam.org/MSA/RIM/software_rim58/) for interpreting thermochronologic data, with the EarthChem website. Make data output generated files in compatible formats for these programs. Explore implementing any programs directly on the website.

EarthChem Workshop on Geochronology – Ar-Ar

Nichols Hall, University of Kansas – May 2, 2008

Agenda

8:45	Overview of Geoinformatics and examples. Demonstration of NAVDAT and EarthChem systems.
9:30	Discussion of reporting requirements for Ar-Ar data. What are the critical items that must be reported? Can we link to IGSN/SESAR for sample information?
11:00	Demonstration of NAVDAT data entry.
11:15	Discussion of how data entry and submission should work for geochronology and thermochronology. Do we need digital lab books? How do legacy data and new data differ? Do data reduction programs contain enough metadata? What level/depth of data documentation is needed or desirable?

Lunch (12:00 – 1:00)

1:00	Continue discussion
2:00	Demonstration of NAVDAT plotting and maps.
2:15	Nature of Ar-Ar geochronology/thermochronology website and geochronology websites in general. What ways do providers and users want to interact with the data? Is it critical to allow reprocessing of data at some level? What sorts of age calculation utilities are needed?
4:00	Discussion of how the website should link to the rest of geoinformatics. What links are needed? What other groups should be involved? How integrated must this be with the main site?
4:30	Wrap up and listing of goals. Identify next steps and key providers/users to move the effort forward.
5:00	Adjourn. Group heads back to Kansas City.

Table 1. Sample Information

Label	Variable Name	Type	Units	Required	Explanations
Sample ID	sampleID	String(50)	Text	required	Sample ID given by researcher
Sample Other Name	sampleOtherName	String(50)	Text	no	Sample other name given by researcher
IGSN Number	igsn	String(50)	Text	required	IGSN Number related to the Sample ID
Longitude	longitude	String(50)	Text	required	Longitude in the E36.3 or W123.45 format
Latitude	latitude	String(50)	Text	required	Latitude in the N36.3 or S23.45 format
Analyst Name	analystName	String(200)	Text	required	Name of the analyst

Note: This table contains basic information about the sample analyzed.

Table 2. Preferred Age Interpretation

Label	Variable Name	Type	Units	Required	Explanations
Experiments Included	experimentsIncluded	String(1000)	Text	required	Experiments included in calculation
Preferred Age	preferredAge	Number	Number in Ma	required	Preferred age in Ma
Preferred Age Sigma	preferredAgeSigma	Number	Number in Ma	required	Preferred age in Ma (uncertainty = 1xSD)
Preferred Age Sigma Internal	preferredAgeSigmaInternal	Number	Number in Ma	required	Preferred age including J-Value uncertainty (uncertainty = 1xSD)
Preferred Age Sigma External	preferredAgeSigmaExternal	Number	Number in Ma	no	Preferred age including all systematic errors (uncertainty = 1xSD)
Preferred Age Type	preferredAgeType	String(50)	Text	required	"Age Plateau, Normal Isochron, Inverse Isochron, Total Gas, Total Gas Volume Weighted, Total Fusion Weighted Mean, Not Specified, Hybrid, Probability Curve Weighted Mean, Combined Isochron"
Preferred Age Classification	preferredAgeClassification	String(50)	Text	required	"Cooling Age, Eruption Age, Crystallization Age, Alteration Age, Minimum Age, Maximum Age, Metamorphic Age, No Interpretation"
Preferred Age Reference	preferredAgeReference	String(200)	Text	required	Full publication reference
Preferred Age Description	preferredAgeDescription	String(1000)	Text	no	Detailed description

Note: This table gives information about the submitter's preferred age interpretation.

Table 3. Interpreted Ages

Label	Variable Name	Type	Units	Required	Explanations
Experiments Included	experimentsIncluded	String(1000)	Text	no	Experiments included in calculation
Interpreted Age	interpretedAge	Number	Number in Ma	no	Any interpreted age in Ma
Interpreted Age Sigma	interpretedAgeSigma	Number	Number in Ma	no	Any interpreted age in Ma (uncertainty = 1xSD)
Interpreted Age Sigma Internal	interpretedAgeSigmaInternal	Number	Number in Ma	no	Any interpreted age including J-Value uncertainty (uncertainty = 1xSD)
Interpreted Age Sigma External	interpretedAgeSigmaExternal	Number	Number in Ma	no	Any interpreted age including all systematic errors (uncertainty = 1xSD)
Interpreted Age Type	interpretedAgeType	String(50)	Text	no	"Age Plateau, Normal Isochron, Inverse Isochron, Total Gas, Total Gas Volume Weighted, Total Fusion Weighted Mean, Not Specified, Hybrid, Probability Curve Weighted Mean, Combined Isochron"
Interpreted Age Classification	interpretedAgeClassification	String(50)	Text	no	"Cooling Age, Eruption Age, Crystallization Age, Alteration Age, Minimum Age, Maximum Age, Metamorphic Age, No Interpretation"
Interpreted Age Reference	interpretedAgeReference	String(200)	Text	no	Full publication reference
Interpreted Age Description	interpretedAgeDescription	String(1000)	Text	no	Detailed description

Note: This table gives information about as many age interpretations a submitter wishes to present.

Table 4. Experiment Parameters

Label	Variable Name	Type	Units	Required	Explanations
Standard Name	standardName	String(10)	Text	required	Standard Name
Standard Reference	standardReference	String(200)	Text	no	Full publication reference
Standard Material	standardMaterial	String(20)	Text	required	"Biotite, Sanidine, Hornblende"
Standard Batch	standardBatch	String(20)	Text	no	Batch number or description
Standard Age	standardAge	Number	Number in Ma	required	Age of the standard
Standard Age Sigma	standardAgeSigma	Number	Number in Ma	no	Age of the standard (uncertainty = 1xSD)
Standard Age 40Ar* Abundance	standardAge40ArAbundance	Number	Number in mol/g	no	40Ar* abundance measured for the standard
Standard Age 40Ar* Abundance Sigma	standardAge40ArAbundanceSigma	Number	Number in mol/g	no	40Ar* abundance measured for the standard (uncertainty = 1xSD)
Standard Age K Abundance	standardAgeKAbundance	Number	Number in wt%	no	K abundance measured for the standard
Standard Age K Abundance Sigma	standardAgeKAbundanceSigma	Number	Number in wt%	no	K abundance measured for the standard (uncertainty = 1xSD)
Standard Age 40Ar*/40K Ratio	standardAge40Ar40KRatio	Number	Dimensionless	no	40Ar*/40K of the standard
Standard Age 40Ar*/40K Ratio Sigma	standardAge40Ar40KRatioSigma	Number	Dimensionless	no	40Ar*/40K of the standard (uncertainty = 1xSD)
Decay Constant 40Ar Total	decayConstant40ArTotal	Number	Number in 1/a	required	Decay constant -- total decay contant
Decay Constant 40Ar Total Sigma	decayConstant40ArTotalSigma	Number	Number in 1/a	required	Decay constant -- total decay contant (uncertainty = 1xSD)
Decay Constant 40Ar Beta	decayConstant40ArBeta	Number	Number in 1/a	no	Decay constant -- partial beta decay contant
Decay Constant 40Ar Beta Sigma	decayConstant40ArBetaSigma	Number	Number in 1/a	no	Decay constant -- partial beta decay contant (uncertainty = 1xSD)
Decay Constant	decayConstant40ArElectron	Number	Number in 1/a	no	Decay constant -- partial

40Ar Electron					electron capture decay contant
Decay Constant 40Ar Electron Sigma	decayConstant40ArElectronSigma	Number	Number in 1/a	no	Decay constant -- partial electron capture decay contant (uncertainty = 1xSD)
Activity 40Ar Beta	activity40ArBeta	Number	Number in 1/gs	no	Activity -- partial beta decay contant
Activity 40Ar Beta Sigma	activity40ArBetaSigma	Number	Number in 1/gs	no	Activity -- partial beta decay contant (uncertainty = 1xSD)
Activity 40Ar Electron	activity40ArElectron	Number	Number in 1/gs	no	Activity -- partial electron capture decay contant
Activity 40Ar Electron Sigma	activity40ArElectronSigma	Number	Number in 1/gs	no	Activity -- partial electron capture decay contant (uncertainty = 1xSD)
Avogadro Number	avogadroNumber	Number	Number in 1/mol	no	Avogradro's number
Solar Year	solarYear	Number	Number in seconds	no	Solar year in seconds
Atomic Weight K	atomicWeightK	Number	Number in g	no	Atomic weight of K
Atomic Weight K Sigma	atomicWeightKSigma	Number	Number in g	no	Atomic weight of K (uncertainty = 1xSD)
Abundance Ratio 40K/K	abundanceRatio40KK	Number	Dimensionless	no	Abundance ratio 40K/K
Abundance Ratio 40K/K Sigma	abundanceRatio40KKSigma	Number	Dimensionless	no	Abundance ratio 40K/K (uncertainty = 1xSD)
J-Value	jValue	Number	Dimensionless	required	J-Value
J-Value Sigma	jValueSigma	Number	Dimensionless	required	J-Value (uncertainty = 1xSD)
Parameters Description	parametersDescription	String(1000)	Text	no	Detailed description

Note: This table gives information about the parameters used in the Ar-Ar experiment.

Table 5. Irradiation Parameters

Label	Variable Name	Type	Units	Required	Explanations
Irradiation Name	irradiationName	String(50)	Text	no	OSU2G03
Irradiation Reactor Name	irradiationReactorName	String(50)	Text	required	"TRIGA, Petten"
Irradiation Total Duration	irradiationTotalDuration	Number	Number in hours	no	Total duration of irradiation
Irradiation End Date and Time	irradiationEndDateTime	Date	Text	no	"Date and time of the end of the irradiation (in ""yyyy:mm:dd:hh:mm:ss.ss"" format)"
Irradiation Power	irradiationPower	Number	Number in MWH	no	Power for irradiation
Irradiation Segment List	irradiationSegmentList	Number	Text	no	"List of all irradiation segments with duration, date, end time and power settings"
Correction 40Ar/36Ar Atmospheric	correction40Ar36ArAtmospheric	Number	Dimensionless	required	Irradiation correction factor 40Ar/36Ar from atmosphere
Correction 40Ar/36Ar Atmospheric Sigma	correction40Ar36ArAtmosphericSigma	Number	Dimensionless	required	Irradiation correction factor 40Ar/36Ar from atmosphere (uncertainty = 1xSD)
Correction 40Ar/36Ar Cosmogenic	correction40Ar36ArCosmogenic	Number	Dimensionless	no	Irradiation correction factor 40Ar/36Ar from cosmogenic
Correction 40Ar/36Ar Cosmogenic Sigma	correction40Ar36ArCosmogenicSigma	Number	Dimensionless	no	Irradiation correction factor 40Ar/36Ar from cosmogenic (uncertainty = 1xSD)
Correction 38Ar/36Ar Atmospheric	correction38Ar36ArAtmospheric	Number	Dimensionless	required	Irradiation correction factor 38Ar/36Ar from atmosphere
Correction 38Ar/36Ar Atmospheric Sigma	correction38Ar36ArAtmosphericSigma	Number	Dimensionless	required	Irradiation correction factor 38Ar/36Ar from atmosphere (uncertainty = 1xSD)

Correction 38Ar/36Ar Cosmogenic	correction38Ar36ArCosmogenic	Number	Dimensionless	no	Irradiation correction factor 38Ar/36Ar from cosmogenic
Correction 38Ar/36Ar Cosmogenic Sigma	correction38Ar36ArCosmogenicSigma	Number	Dimensionless	no	Irradiation correction factor 38Ar/36Ar from cosmogenic (uncertainty = 1xSD)
Correction 39Ar/37Ar Calcium	correction39Ar37ArCalcium	Number	Dimensionless	required	Irradiation correction factor 39Ar/37Ar from calcium
Correction 39Ar/37Ar Calcium Sigma	correction39Ar37ArCalciumSigma	Number	Dimensionless	required	Irradiation correction factor 39Ar/37Ar from calcium (uncertainty = 1xSD)
Correction 38Ar/37Ar Calcium	correction38Ar37ArCalcium	Number	Dimensionless	required	Irradiation correction factor 38Ar/37Ar from calcium
Correction 38Ar/37Ar Calcium Sigma	correction38Ar37ArCalciumSigma	Number	Dimensionless	required	Irradiation correction factor 38Ar/37Ar from calcium (uncertainty = 1xSD)
Correction 36Ar/37Ar Calcium	correction36Ar37ArCalcium	Number	Dimensionless	required	Irradiation correction factor 36Ar/37Ar from calcium
Correction 36Ar/37Ar Calcium Sigma	correction36Ar37ArCalciumSigma	Number	Dimensionless	required	Irradiation correction factor 36Ar/37Ar from calcium (uncertainty = 1xSD)
Correction 40Ar/39Ar Potassium	correction40Ar39ArPotassium	Number	Dimensionless	required	Irradiation correction factor 40Ar/39Ar from potassium
Correction 40Ar/39Ar Potassium Sigma	correction40Ar39ArPotassiumSigma	Number	Dimensionless	required	Irradiation correction factor 40Ar/39Ar from potassium (uncertainty = 1xSD)
Correction 38Ar/39Ar Potassium	correction38Ar39ArPotassium	Number	Dimensionless	required	Irradiation correction factor 38Ar/39Ar from potassium
Correction 38Ar/39Ar Potassium	correction38Ar39ArPotassiumSigma	Number	Dimensionless	required	Irradiation correction factor 38Ar/39Ar from potassium (uncertainty = 1xSD)

Sigma					
36Ar/38Ar Chlorine (production ratio)	chlorineProductionRatio36Ar38Ar	Number	Dimensionless	no	Irradiation correction factor 36Ar/38Ar from chlorine
36Ar/38Ar Chlorine (production ratio) Sigma	chlorineProductionRatio36Ar38ArSigma	Number	Dimensionless	no	Irradiation correction factor 36Ar/38Ar from chlorine (uncertainty = 1xSD)
Correction K/Ca	correctionKCa	Number	Dimensionless	no	Molar correction factor for K/Ca
Correction K/Ca Sigma	correctionKCaSigma	Number	Dimensionless	no	Molar correction factor for K/Ca (uncertainty = 1xSD)
Correction K/Cl	correctionKCl	Number	Dimensionless	no	Molar correction factor for K/Cl
Correction K/Cl Sigma	correctionKClSigma	Number	Dimensionless	no	Molar correction factor for K/Cl (uncertainty = 1xSD)
Correction Ca/Cl	correctionCaCl	Number	Dimensionless	no	Molar correction factor for Ca/Cl
Correction Ca/Cl Sigma	correctionCaClSigma	Number	Dimensionless	no	Molar correction factor for Ca/Cl (uncertainty = 1xSD)
Irradiation Description	irradiationDescription	String(1000)	Text	no	Detailed description

Note: This table gives information about sample irradiation.

Table 6. Experiment

Label	Variable Name	Type	Units	Required	Explanations
Experiment Identifier	experimentIdentifier	String(50)	Text	required	KOPA-299-1
Experiment Type	experimentType	String(50)	Text	required	"Incremental Heating, Total Fusion, Incremental Crushing, Total Crushing"
Sample Material	sampleMaterial	String(10)	Text	required	Material analyzed (mineral and/or rock type)
Sample Material Type	sampleMaterialType	String(50)	Text	required	"Single Crystal, Multi Crystal, In Situ, Bulk, Groundmass"
Sample Grain Size Fraction	sampleGrainSizeFraction	String(10)	Text	no	Grain size fraction of material analyzed
Sample Treatment	sampleTreatment	String(1000)	Text	no	Description of sample treatment
Sample Weight	sampleWeight	Number	Number in mg	no	Loaded sample weight in mg
Sample IGSN Number	igsn	String(10)	Text	no	IGSN daugther number related to the Sample ID and Sample IGSN
Project Name	projectName	String(50)	Text	no	Project name
Extraction Method	extractionMethod	String(100)	Text	no	"Encapsulation, Laser Bulk Heating, In Situ Laser, Furnace, Crushing"
Mass Spectrometer	massSpectrometer	String(100)	Text	no	"Mass spectrometer model (e.g. MAP 215-50, ARGUS, ARGUS VI, Noblesse, Helix)"
Laboratory	laboratory	String(100)	Text	required	"Laboratory (e.g. COAS, Oregon State University, Corvallis, Oregon, USA)"
Laboratory Reference	laboratoryReference	String(200)	Text	no	Full publication reference describing laboratory and methodology applied
Instrument Name	instrumentName	String(100)	Text	no	Laboratory name or identifier of instrument
Acquisition Software	acquisitionSoftware	String(200)	Text	no	Acquistion software and version (e.g. Mass Spec v23.1)
Data Reduction Software	dataReductionSoftware	String(200)	Text	no	"Data reducation software and version (e.g. Mass Spec v23.2, ArArCALC v2.5)"
Sample	sampleDescription	String(100)	Text	no	Description of sample analyzed

Description						
Experiment Description	experimentDescription	String(100)	Text	no		Description of exeperiment carried out

Note: This table gives information about each experiment.

Table 7. Age

Label	Variable Name	Type	Units	Required	Explanations
Steps in Age Plateau	stepsInAgePlateau	Number	Custom	no	Step included in calculation
Weighted Plateau 40Ar/39Ar Ratio	weightedPlateau40Ar39ArRatio	Number	Number	no	Weighted plateau 40Ar(rad)/39Ar(k) ratio
Weighted Plateau 40Ar/39Ar Ratio Sigma	weightedPlateau40Ar39ArRatioSigma	Number	Number	no	Weighted plateau 40Ar(rad)/39Ar(k) ratio (uncertainty = 1xSD)
Weighted Plateau Age	weightedPlateauAge	Number	Number in Ma	no	Weighted plateau age
Weighted Plateau Age Sigma	weightedPlateauAgeSigma	Number	Number in Ma	no	Weighted plateau age (uncertainty = 1xSD)
Weighted Plateau Age Sigma Internal	weightedPlateauAgeSigmaInternal	Number	Number in Ma	no	Weighted plateau age including J-Value uncertainty (uncertainty = 1xSD)
Weighted Plateau Age Sigma External	weightedPlateauAgeSigmaExternal	Number	Number in Ma	no	Weighted plateau age including all systematic errors (uncertainty = 1xSD)
Weighted Plateau K/Ca Ratio	weightedPlateauKCaRatio	Number	Number in Ma	no	Weighted plateau K/Ca ratio
Weighted Plateau K/Ca Ratio Sigma	weightedPlateauKCaRatioSigma	Number	Number in Ma	no	Weighted plateau K/Ca ratio (uncertainty = 1xSD)
Weighted Plateau K/Cl Ratio	weightedPlateauKClRatio	Number	Number in Ma	no	Weighted plateau K/Cl ratio
Weighted Plateau K/Cl Ratio Sigma	weightedPlateauKClRatioSigma	Number	Number in Ma	no	Weighted plateau K/Cl ratio (uncertainty = 1xSD)
Weighted Plateau MSWD	weightedPlateauMSWD	Number	Dimensionless	no	Weighted plateau MSWD
Weighted Plateau Error	weightedPlateauErrorMagnification	Number	Dimensionless	no	Weighted plateau error magnification factor based

Magnification					on Sqr(MSWD)
Weighted Plateau Width	weightedPlateauWidth	Number	Number in %	no	Weighted plateau width in percent of total amount 39Ar(k) released
Weighted Plateau N	weightedPlateauN	Integer	Integer	no	Number of measurements included in weighted age plateau
Steps in Total Gas/Fusion	stepsInTotalGasFusion	Number	Custom	no	Step included in calculation
Total Gas/Fusion 40Ar/39Ar Ratio	totalGasFusion40Ar39ArRatio	Number	Number	required	Total gas 40Ar(rad)/39Ar(k) ratio
Total Gas/Fusion 40Ar/39Ar Ratio Sigma	totalGasFusion40Ar39ArRatioSigma	Number	Number	required	Total gas 40Ar(rad)/39Ar(k) ratio (uncertainty = 1xSD)
Total Gas/Fusion Age	totalGasFusionAge	Number	Number in Ma	required	Total gas age
Total Gas/Fusion Age Sigma	totalGasFusionAgeSigma	Number	Number in Ma	required	Total gas age (uncertainty = 1xSD)
Total Gas/Fusion Age Sigma Internal	totalGasFusionAgeSigmaInternal	Number	Number in Ma	no	Total gas age including J-Value uncertainty (uncertainty = 1xSD)
Total Gas/Fusion Age Sigma External	totalGasFusionAgeSigmaExternal	Number	Number in Ma	no	Total gas age including all systematic errors (uncertainty = 1xSD)
Total Gas/Fusion K/Ca Ratio	totalGasFusionKCaRatio	Number	Number in Ma	no	Total gas K/Ca ratio
Total Gas/Fusion K/Ca Ratio Sigma	totalGasFusionKCaRatioSigma	Number	Number in Ma	no	Total gas K/Ca ratio (uncertainty = 1xSD)
Total Gas/Fusion K/Cl Ratio	totalGasFusionKClRatio	Number	Number in Ma	no	Total gas K/Cl ratio
Total Gas/Fusion K/Cl Ratio Sigma	totalGasFusionKClRatioSigma	Number	Number in Ma	no	Total gas K/Cl ratio (uncertainty = 1xSD)

Total Gas/Fusion MSWD	totalGasFusionMSWD	Number	Dimensionless	no	Weighted plateau MSWD
Total Gas/Fusion Error Magnification	totalGasFusionErrorMagnification	Number	Dimensionless	no	Weighted plateau error magnification factor based on Sqr(MSWD)
Total Gas N	totalGasFusionN	Integer	Integer	required	Number of measurements included in total gas calculations
Steps in Normal Isochron	stepsInNormalIsochron	Number	Custom	no	Step included in calculation
Normal Isochron 40Ar/39Ar Ratio	normalIsochron40Ar39ArRatio	Number	Number	no	Normal isochron 40Ar(rad)/39Ar(k) ratio
Normal Isochron 40Ar/39Ar Ratio Sigma	normalIsochron40Ar39ArRatioSigma	Number	Number	no	Normal isochron 40Ar(rad)/39Ar(k) ratio (uncertainty = 1xSD)
Normal Isochron Age	normalIsochronAge	Number	Number in Ma	no	Normal isochron age
Normal Isochron Age Sigma	normalIsochronAgeSigma	Number	Number in Ma	no	Normal isochron age (uncertainty = 1xSD)
Normal Isochron Age Sigma Internal	normalIsochronAgeSigmaInternal	Number	Number in Ma	no	Normal isochron age including J-Value uncertainty (uncertainty = 1xSD)
Normal Isochron Age Sigma External	normalIsochronAgeSigmaExternal	Number	Number in Ma	no	Normal isochron age including all systematic errors (uncertainty = 1xSD)
Normal Isochron 40Ar/36Ar Ratio	normalIsochron40Ar36ArRatio	Number	Number in Ma	no	Normal isochron 40Ar/36Ar atmospheric intercept
Normal Isochron 40Ar/36Ar Ratio Sigma	normalIsochron40Ar36ArRatioSigma	Number	Number in Ma	no	Normal isochron 40Ar/36Ar atmospheric intercept (uncertainty = 1xSD)
Normal Isochron MSWD	normalIsochronMSWD	Number	Dimensionless	no	Normal isochron MSWD
Normal Isochron Error Magnification	normalIsochronErrorMagnification	Number	Dimensionless	no	Normal isochron error magnification factor based on Sqr(MSWD)
Normal Isochron	normalIsochronConvergence	Number	Dimensionless	no	Normal isochron

Convergence					convergence in regression
Normal Isochron Iterations	normalIsochronIterations	Integer	Integer	no	Normal isochron number of iterations to reach convergence
Normal Isochron N	normalIsochronN	Integer	Integer	no	Number of measurements included in weighted age isochron
Steps in Inverse Isochron	stepsInInverseIsochron	Number	Custom	no	Step included in calculation
Inverse Isochron 40Ar/39Ar Ratio	inverseIsochron40Ar39ArRatio	Number	Number	no	Inverse isochron 40Ar(rad)/39Ar(k) ratio
Inverse Isochron 40Ar/39Ar Ratio Sigma	inverseIsochron40Ar39ArRatioSigma	Number	Number	no	Inverse isochron 40Ar(rad)/39Ar(k) ratio (uncertainty = 1xSD)
Inverse Isochron Age	inverseIsochronAge	Number	Number in Ma	no	Inverse isochron age
Inverse Isochron Age Sigma	inverseIsochronAgeSigma	Number	Number in Ma	no	Inverse isochron age (uncertainty = 1xSD)
Inverse Isochron Age Sigma Internal	inverseIsochronAgeSigmaInternal	Number	Number in Ma	no	Inverse isochron age including J-Value uncertainty (uncertainty = 1xSD)
Inverse Isochron Age Sigma External	inverseIsochronAgeSigmaExternal	Number	Number in Ma	no	Inverse isochron age including all systematic errors (uncertainty = 1xSD)
Inverse Isochron 40Ar/36Ar Ratio	inverseIsochron40Ar36ArRatio	Number	Number in Ma	no	Inverse isochron 40Ar/36Ar atmospheric intercept
Inverse Isochron 40Ar/36Ar Ratio Sigma	inverseIsochron40Ar36ArRatioSigma	Number	Number in Ma	no	Inverse isochron 40Ar/36Ar atmospheric intercept (uncertainty = 1xSD)
Inverse Isochron MSWD	inverseIsochronMSWD	Number	Dimensionless	no	Inverse isochron MSWD
Inverse Isochron Error Magnification	inverseIsochronErrorMagnification	Number	Dimensionless	no	Inverse isochron error magnification factor based on Sqr(MSWD)
Inverse Isochron Convergence	inverseIsochronConvergence	Number	Dimensionless	no	Inverse isochron convergence in regression
Inverse Isochron Iterations	inverseIsochronIterations	Integer	Integer	no	Inverse isochron number of iterations to reach

					convergence
Inverse Isochron N	inverseIsochronN	Integer	Integer	no	Number of measurements included in weighted age isochron
Age Description	ageDescription	String(1000)	Text	no	Detailed description

Note: Table gives information about ages derived from the measurements.

Table 8. Measurements

Label	Variable Name	Type	Units	Required	Explanations
Measurement Number	measurementNumber	String(50)	Text	required	"Measurement indentifier or lab number (e.g. 03C3120, 93L0256A)"
Measurement Date and Time	measurementDateTime	Date	Text	required	"Date and time of the measurement (in the ""yyyy:mm:dd:hh:mm:ss.ss"" format)"
Temperature	temperature	Number	Number	required	Temperature for incremental heating step
Temperature Sigma	temperatureSigma	Number	Number	no	Temperature for incremental heating step
Temperature Unit	temperatureUnit	String(10)	Text	required	"Temperature unit (e.g. °K, °C, Laser(W), Laser(%))"
Heating Duration	heatingDuration	Number	Number in seconds	no	Duration of sample heating in seconds
Isolation Duration	isolationDuration	Number	Number in minutes	no	Duration of sample isolation in extraction line in minutes
Irradiation Name	irradiationName	String(50)	Text	no	Name for irradiation (e.g. OSU2G03)
Mass Discrimination Factor	mdfValue	Number	Dimensionless	required	Mass discrimination factor
Mass Discrimination Factor Sigma	mdfValueSigma	Number	Dimensionless	required	Mass discrimination factor (uncertainty = 1xSD)
Mass Discrimination Law Applied	mdfLawApplied	String(20)	Text	required	"Mass discrimination law applied (e.g. Linear, Exponentional, Power Law)"
Mass Discrimination 40Ar/36Ar Standard Ratio	mdf40Ar36ArStandardRatio	Number	Dimensionless	required	Mass discrimination 40Ar/36Ar standard ratio
Mass Discrimination 40Ar/36Ar Standard Ratio Sigma	mdf40Ar36ArStandardRatioSigma	Number	Dimensionless	required	Mass discrimination 40Ar/36Ar standard ratio
Fraction 40Ar Radiogenic	fraction40ArRadiogenic	Number	Number in %	no	Fraction radiogenic 40Ar component in incremental heating step
Fraction 39Ar Potassium	fraction39ArPotassium	Number	Number in %	no	Fraction 39ar(k) from total amount of gas released or increment size

Measured Age	measuredAge	Number	Number in Ma	required	Age of incremental heating step
Measured Age Sigma	measuredAgeSigma	Number	Number in Ma	required	Age of incremental heating step (uncertainty = 1xSD)
Measured K/Ca Ratio	measuredKCaRatio	Number	Dimensionless	no	Molar K/Ca ratio
Measured K/Ca Ratio Sigma	measuredKCaRatioSigma	Number	Dimensionless	no	Molar K/Ca ratio (uncertainty = 1xSD)
Measured K/Cl Ratio	measuredKClRatio	Number	Dimensionless	no	Molar K/Cl ratio
Measured K/Cl Ratio Sigma	measuredKClRatioSigma	Number	Dimensionless	no	Molar K/Cl ratio (uncertainty = 1xSD)
Intercept 36Ar	intercept36Ar	Number	Custom	required	"Baseline, blank and fractionation corrected intercept for mass 36, dectector intercalibrated"
Intercept 36Ar Sigma	intercept36ArSigma	Number	Custom	required	Intercept for mass 36 (uncertainty = 1xSD)
Intercept 36Ar Regression Type	intercept36ArRegressionType	String(20)	Text	no	"Intercept for mass 36 regression type (e.g. Linear, Parabolic, Exponentional, Average)"
Intercept 37Ar	intercept37Ar	Number	Custom	required	"Baseline, blank and fractionation corrected intercept for mass 37, dectector intercalibrated"
Intercept 37Ar Sigma	intercept37ArSigma	Number	Custom	required	Intercept for mass 37 (uncertainty = 1xSD)
Intercept 37Ar Regression Type	intercept37ArRegressionType	String(20)	Text	no	"Intercept for mass 37 regression type (e.g. Linear, Parabolic, Exponentional, Average)"
Intercept 38Ar	intercept38Ar	Number	Custom	required	"Baseline, blank and fractionation corrected intercept for mass 38, dectector intercalibrated"
Intercept 38Ar Sigma	intercept38ArSigma	Number	Custom	required	Intercept for mass 38 (uncertainty = 1xSD)
Intercept 38Ar Regression Type	intercept38ArRegressionType	String(20)	Text	no	"Intercept for mass 38 regression type (e.g. Linear, Parabolic, Exponentional, Average)"
Intercept 39Ar	intercept39Ar	Number	Custom	required	"Baseline, blank and

					fractionation corrected intercept for mass 39, dectector intercalibrated"
Intercept 39Ar Sigma	intercept39ArSigma	Number	Custom	required	Intercept for mass 39 (uncertainty = 1xSD)
Intercept 39Ar Regression Type	intercept39ArRegressionType	String(20)	Text	no	"Intercept for mass 39 regression type (e.g. Linear, Parabolic, Exponentional, Average)"
Intercept 40Ar	intercept40Ar	Number	Custom	required	"Baseline, blank and fractionation corrected intercept for mass 40, dectector intercalibrated"
Intercept 40Ar Sigma	intercept40ArSigma	Number	Custom	required	Intercept for mass 40 (uncertainty = 1xSD)
Intercept 40Ar Regression Type	intercept40ArRegressionType	String(20)	Text	no	"Intercept for mass 40 regression type (e.g. Linear, Parabolic, Exponentional, Average)"
Intercept Unit	interceptUnit	String(10)	Text	no	"Intercept unit (e.g. Volt, Ampere)"
Blank 36Ar	blank36Ar	Number	Custom	no	Total procedure blank for mass 36
Blank 36Ar Sigma	blank36ArSigma	Number	Custom	no	Total procedure blank for mass 36 (uncertainty = 1xSD)
Blank 37Ar	blank37Ar	Number	Custom	no	Total procedure blank for mass 37
Blank 37Ar Sigma	blank37ArSigma	Number	Custom	no	Total procedure blank for mass 37 (uncertainty = 1xSD)
Blank 38Ar	blank38Ar	Number	Custom	no	Total procedure blank for mass 38
Blank 38Ar Sigma	blank38ArSigma	Number	Custom	no	Total procedure blank for mass 38 (uncertainty = 1xSD)
Blank 39Ar	blank39Ar	Number	Custom	no	Total procedure blank for mass 39
Blank 39Ar Sigma	blank39ArSigma	Number	Custom	no	Total procedure blank for mass 39 (uncertainty = 1xSD)

Blank 40Ar	blank40Ar	Number	Custom	no	Total procedure blank for mass 40
Blank 40Ar Sigma	blank40ArSigma	Number	Custom	no	Total procedure blank for mass 40 (uncertainty = 1xSD)
Blank Unit	blankUnit	String(10)	Text	no	"Procedure blank unit (e.g. Volt, Ampere)"
Corrected Total 40Ar/39Ar Ratio	correctedTotal40Ar39ArRatio	Number	Dimensionless	no	"Total 40Ar/39Ar ratio (i.e. corrected for blanks, fractionation and decay after irradiation)"
Corrected Total 40Ar/39Ar Ratio Sigma	correctedTotal40Ar39ArRatioSigma	Number	Dimensionless	no	Total 40Ar/39Ar ratio (uncertainty = 1xSD)
Corrected Total 37Ar/39Ar Ratio	correctedTotal37Ar39ArRatio	Number	Dimensionless	no	"Total 37Ar/39Ar ratio (i.e. corrected for blanks, fractionation and decay after irradiation)"
Corrected Total 37Ar/39Ar Ratio Sigma	correctedTotal37Ar39ArRatioSigma	Number	Dimensionless	no	Total 37Ar/39Ar ratio (uncertainty = 1xSD)
Corrected Total 36Ar/39Ar Ratio	correctedTotal36Ar39ArRatio	Number	Dimensionless	no	"Total 36Ar/39Ar ratio (i.e. corrected for blanks, fractionation and decay after irradiation)"
Corrected Total 36Ar/39Ar Ratio Sigma	correctedTotal36Ar39ArRatioSigma	Number	Dimensionless	no	Total 36Ar/39Ar ratio (uncertainty = 1xSD)
Corrected 40Ar(rad)/39Ar(k) Ratio	corrected40ArRad39ArKRatio	Number	Dimensionless	no	"Corrected 40Ar(rad)/39Ar(k) ratio (i.e. corrected for blanks, fractionation and decay after irradiation)"
Corrected 40Ar(rad)/39Ar(k) Ratio Sigma	corrected40ArRad39ArKRatioSigma	Number	Dimensionless	no	Corrected 40Ar(rad)/39Ar(k) ratio (uncertainty = 1xSD)
Corrected 39Ar(k)/36Ar(atm) Ratio	corrrected39ArK36ArAtmRatio	Number	Dimensionless	no	"Corrected 39Ar(k)/36Ar(atm) ratio (used in normal isochron) (i.e. corrected for blanks, fractionation and decay after irradiation)"
Corrected 39Ar(k)/36Ar(atm) Ratio	corrrected39ArK36ArAtmRatioSigma	Number	Dimensionless	no	Corrected 39Ar(k)/36Ar(atm) ratio (used in normal

Sigma					isochron) (uncertainty = 1xSD)
Corrected 40Ar(rad+atm)/36Ar(atm) Ratio	corrrected40ArRadAtm36ArAtmRatio	Number	Dimensionless	no	"Corrected 40Ar(rad+atm)/36Ar(atm) ratio (used in normal isochron) (i.e. corrected for blanks, fractionation and decay after irradiation)"
Corrected 40Ar(rad+atm)/36Ar(atm) Ratio Sigma	corrrected40ArRadAtm36ArAtmRatioSigma	Number	Dimensionless	no	Corrected 40Ar(rad+atm)/36Ar(atm) ratio (used in normal isochron) (uncertainty = 1xSD)
Corrected 39Ar(k)/40Ar(rad+atm) Ratio	corrrected39ArK40ArRadAtmRatio	Number	Dimensionless	no	"Corrected 39Ar(k)/40Ar(rad+atm) ratio (used in inverse isochron) (i.e. corrected for blanks, fractionation and decay after irradiation)"
Corrected 39Ar(k)/40Ar(rad+atm) Ratio Sigma	corrrected39ArK40ArRadAtmRatioSigma	Number	Dimensionless	no	Corrected 39Ar(k)/40Ar(rad+atm) ratio (used in inverse isochron) (uncertainty = 1xSD)
Corrected 36Ar(atm)/40Ar(rad+atm) Ratio	corrrected36ArAtm40ArRadAtmRatio	Number	Dimensionless	no	"Corrected 36Ar(atm)/40Ar(rad+atm) ratio (used in inverse isochron) (i.e. corrected for blanks, fractionation and decay after irradiation)"
Corrected 36Ar(atm)/40Ar(rad+atm) Ratio Sigma	corrrected36ArAtm40ArRadAtmRatioSigma	Number	Dimensionless	no	Corrected 36Ar(atm)/40Ar(rad+atm) ratio (used in inverse isochron) (uncertainty = 1xSD)
Correlation Coefficient 40/36 over 39/36	corrCoefficient4036over3936	Number	Dimensionless	no	Correlation coefficient (used in normal isochron)
Correlation Coefficient 36/40 over 39/40	corrCoefficient3640over3940	Number	Dimensionless	no	Correlation coefficient (used in inverse isochron)
Corrected 36Ar Atmospheric	corrected36ArAtmospheric	Number	Number	no	Corrected 36Ar component from atmosphere
Corrected 36Ar	corrected36ArAtmosphericSigma	Number	Number	no	Corrected 36Ar component

Atmospheric Sigma					from atmosphere (uncertainty = 1xSD)
Corrected 36Ar Cosmogenic	corrected36ArCosmogenic	Number	Number	no	Corrected 36Ar component from cosmogenic input
Corrected 36Ar Cosmogenic Sigma	corrected36ArCosmogenicSigma	Number	Number	no	Corrected 36Ar component from cosmogenic input (uncertainty = 1xSD)
Corrected 36Ar Calcium	corrected36ArCalcium	Number	Number	no	Corrected 36Ar component from calcium
Corrected 36Ar Calcium Sigma	corrected36ArCalciumSigma	Number	Number	no	Corrected 36Ar component from calcium (uncertainty = 1xSD)
Corrected 36Ar Chlorine	corrected36ArChlorine	Number	Number	no	Corrected 36Ar component from chlorine
Corrected 36Ar Chlorine Sigma	corrected36ArChlorineSigma	Number	Number	no	Corrected 36Ar component from chlorine (uncertainty = 1xSD)
Corrected 37Ar Calcium	corrected37ArCalcium	Number	Number	no	Corrected 37Ar component from calcium
Corrected 37Ar Calcium Sigma	corrected37ArCalciumSigma	Number	Number	no	Corrected 37Ar component from calcium (uncertainty = 1xSD)
Corrected 38Ar Atmospheric	corrected38ArAtmospheric	Number	Number	no	Corrected 38Ar component from atmosphere
Corrected 38Ar Atmospheric Sigma	corrected38ArAtmosphericSigma	Number	Number	no	Corrected 38Ar component from atmosphere (uncertainty = 1xSD)
Corrected 38Ar Cosmogenic	corrected38ArCosmogenic	Number	Number	no	Corrected 38Ar component from cosmogenic input
Corrected 38Ar Cosmogenic Sigma	corrected38ArCosmogenicSigma	Number	Number	no	Corrected 38Ar component from cosmogenic input (uncertainty = 1xSD)
Corrected 38Ar Calcium	corrected38ArCalcium	Number	Number	no	Corrected 38Ar component from calcium
Corrected 38Ar Calcium Sigma	corrected38ArCalciumSigma	Number	Number	no	Corrected 38Ar component from calcium (uncertainty = 1xSD)
Corrected 38Ar Chlorine	corrected38ArChlorine	Number	Number	no	Corrected 38Ar component from chlorine
Corrected 38Ar Chlorine Sigma	corrected38ArChlorineSigma	Number	Number	no	Corrected 38Ar component from chlorine (uncertainty =

					1xSD)
Corrected 38Ar Potassium	corrected38ArPotassium	Number	Number	no	Corrected 38Ar component from potassium
Corrected 38Ar Potassium Sigma	corrected38ArPotassiumSigma	Number	Number	no	Corrected 38Ar component from potassium (uncertainty = 1xSD)
Corrected 39Ar Calcium	corrected39ArCalcium	Number	Number	no	Corrected 39Ar component from calcium
Corrected 39Ar Calcium Sigma	corrected39ArCalciumSigma	Number	Number	no	Corrected 39Ar component from calcium (uncertainty = 1xSD)
Corrected 39Ar Potassium	corrected39ArPotassium	Number	Number	no	Corrected 39Ar component from potassium
Corrected 39Ar Potassium Sigma	corrected39ArPotassiumSigma	Number	Number	no	Corrected 39Ar component from potassium (uncertainty = 1xSD)
Corrected 40Ar Atmospheric	corrected40ArAtmospheric	Number	Number	no	Corrected 40Ar component from atmosphere
Corrected 40Ar Atmospheric Sigma	corrected40ArAtmosphericSigma	Number	Number	no	Corrected 40Ar component from atmosphere (uncertainty = 1xSD)
Corrected 40Ar Cosmogenic	corrected40ArCosmogenic	Number	Number	no	Corrected 40Ar component from cosmogenic input
Corrected 40Ar Cosmogenic Sigma	corrected40ArCosmogenicSigma	Number	Number	no	Corrected 40Ar component from cosmogenic input (uncertainty = 1xSD)
Corrected 40Ar Potassium	corrected40ArPotassium	Number	Number	no	Corrected 40Ar component from potassium
Corrected 40Ar Potassium Sigma	corrected40ArPotassiumSigma	Number	Number	no	Corrected 40Ar component from potassium (uncertainty = 1xSD)
Corrected 40Ar Radiogenic	corrected40ArRadiogenic	Number	Number	no	Corrected 40Ar component from radiogenic potassium
Corrected 40Ar Radiogenic Sigma	corrected40ArRadiogenicSigma	Number	Number	no	Corrected 40Ar component from radiogenic potassium (uncertainty = 1xSD)
Measurement Description	measurementDescription	String(1000)	Text	no	Detailed description

Note: This table gives information about measurements for the Ar in the sample.