I. Methods - $^{40}Ar/^{39}Ar$ dating

Mica concentrates were separated from rock chips by mechanical processing included crushing in a steel pestle and mortar until disaggregation to a size fraction of 0.7-0.5 mm. Concentrates were ultrasonically washed in Milli-Q water and after hand-picked under binocular microscope to select only optically fresh grains, which were loaded into a 21-pit aluminum disk along with the Fish Canyon sanidine (FCs age = 28.305 Ma; Renne et al., 2010) and neutron-flux irradiated for 14 hours in the inner-core Cd-lined CLICIT facility of the Oregon State University TRIGA reactor (USA). Irradiated grains of the FCs standard and unknown samples were loaded into 1.5 mm diameter pits drilled in a copper disk to be further heated by a solid state Nd:YVO_4 laser (532nm). The laser is coupled to an integrated system consisting of an all-metal commercial extraction line connected to an ARGUS VI® multi-collector mass spectrometer operating at the Isotope Geology Research Center of the University of São Paulo (Brazil). The analytical routine consisted of heating the samples (and FC standard) for up to 60 seconds at each step while circling the laser spot over the pit. The gases released by the sample were then expanded into the clean-up line using pneumatic valves to remove the undesired (active) gases – H_2O, CO_2 and others. The cleaning process involves two successive stages of purification before introducing the gas into the mass spectrometer. Ar isotopes were measured in Faraday cup detectors with resistances of 10^{11} ohm (for the ^{40}Ar isotope) and 10^{12} ohm (for isotopes $^{39-36}Ar$), under an acceleration voltage of 4.694 kV and an ion trap current of 200 µA. Blanks were run every four analyses in an identical routine as the unknown analyses, while air pipette shots were analyzed at the beginning and ending of each run (or workday) to monitor efficiency and mass fractionation. Data reduction (including correction for nuclear interferences), error propagation and age calculation were all performed using the software ArArCALC v2.5.2 (Koppers, 2002). The assumed K λ_{tot} is 5.543 x 10^{-10} a^{-1} (Steiger and Jäger, 1977). As a first approach, the analyses were tested for the criteria of calculation of a "plateau age", which include three or more consecutive steps concordant within 2σ error and summing >50% of the total ^{39}Ar released. When these criteria are not achieved, we report the results as weighted mean ages (WMA) calculated with the coherent steps at 2σ (or 3σ), even they are not exactly consecutive. Plotting of the results is shown through graphs including all heating steps (plateau age, or disturbed spectrum) or weighted mean age graphs. For these latter, the graphs were generated using the online version of the Isoplot R (Vermeesch, 2018).

Koppers, A.A.P. 2002. ArArCALC – software for $^{40}Ar/^{39}Ar$ age calculations. Computers and Geosciences, 28, 605-619.

Renne, P.R., Mundil, R., Balco, G., Min, K., and Ludwig, K.R., 2010, Joint determination of 40K decay constants and 40Ar*/40K for the Fish Canyon sanidine standard, and improved accuracy for 40Ar/39Ar geochronology: Geochimica et Cosmochimica Acta, v. 74, p. 5349–5367, doi:10.1016/j.gca.2010.06.017.

Steiger, R.H., and Jäger, E., 1977, Subcommission on Geochronology; convention on the use of decay constants in geochronology and cosmochronology: Earth and Planetary Science Letters, v. 36, p. 359–362.

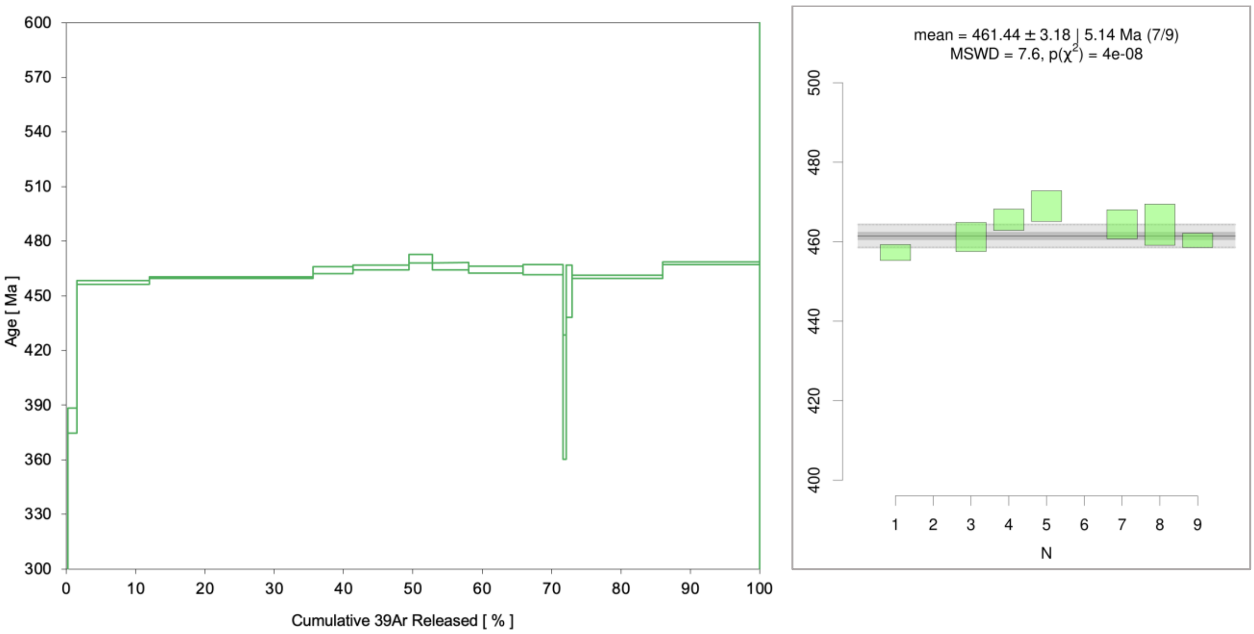
Vermeesch, P. 2018. Isoplot R: a free and open toolbox for geochronology. Geoscience Frontiers, 9, 1479-1493.

II. Results

A total of 24 samples were investigated for Ar geochronology, collected from granites and pegmatites and aplite veins exposed at Zebreira (1), Idanha-a-Nova (3), Penamacor-Orca (5), Argemela (4), Panasqueira (3), Monsanto (5) and Medelín (3) sites. The major drawbacks that arose from the analytical experiments concern to $^{40}Ar^*$ distribution. Although analyses had been carried out on multigrain aliquots, the accentuated disturbance of the heating patterns even in very small quantity (<5 mg) attest to heterogeneity at grain scale, which may be easily associated to hydrothermal conditions described for some of the investigated sites.

However, the Ar/Ar ages were good enough to unravel some open issues and also were generally coincident with previously published geochronological data for, for instance, the Idanha-a Nova site. The figures below illustrate the Ar/Ar results obtained for muscovite and biotite samples investigated in this project.

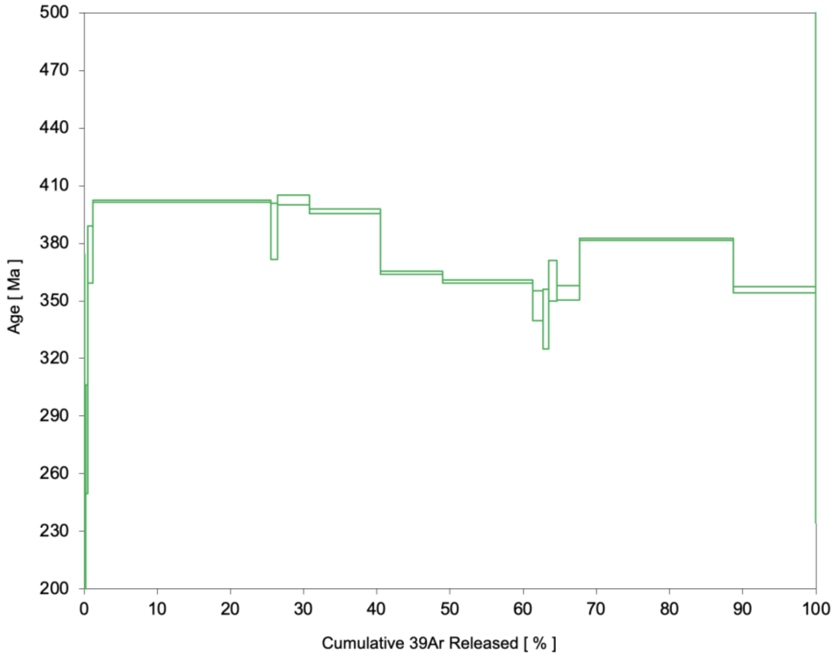
1) ZEBREIRA site



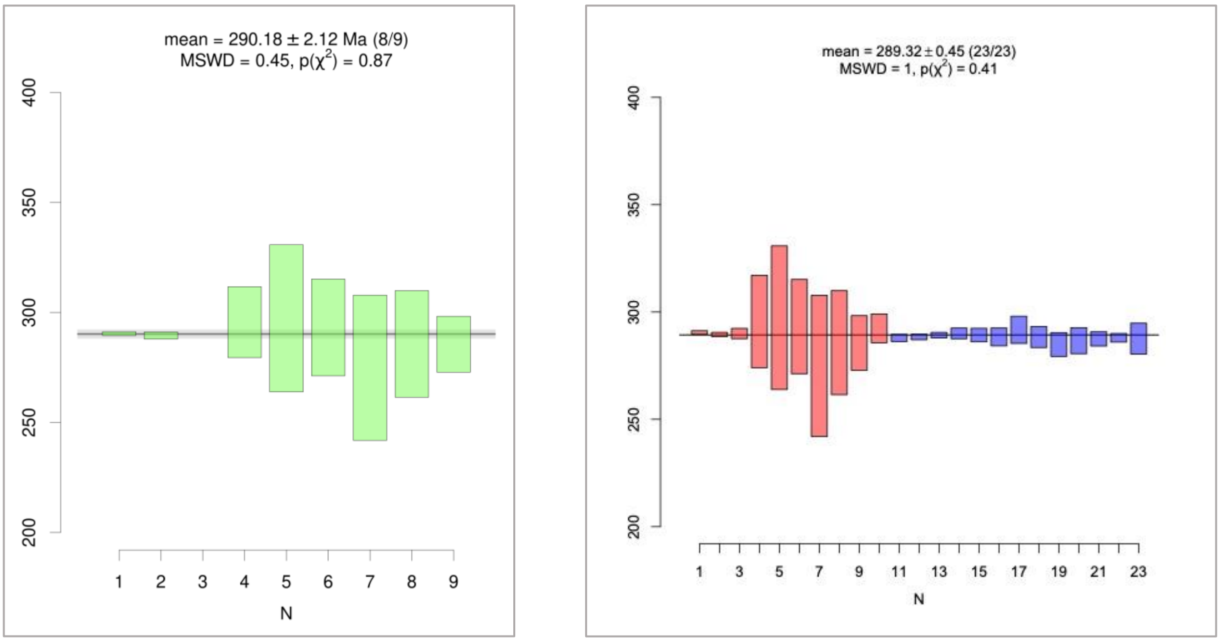
Granite ZEB#4: analyses of muscovite extracted from this sample provided a disturbed heating spectrum from which no plateau age could be calculated. Seven intermediate steps were used to calculated a WMA of 461.4 ± 3.2 Ma, which is similar to the total fusion age (equivalent to a K/Ar age) of 460.9± 2.2 Ma calculated using all apparent ages (steps). These results were only slightly younger than the U-Pb zircon age obtained for the same sample – 468.4 ± 5.4 Ma.

2. IDANHA-A-NOVA site

Three samples were selected for mica Ar/Ar dating: one of muscovite (g_IDN#5) and two of biotite (g_IDN#6 and gf_IDN#4).



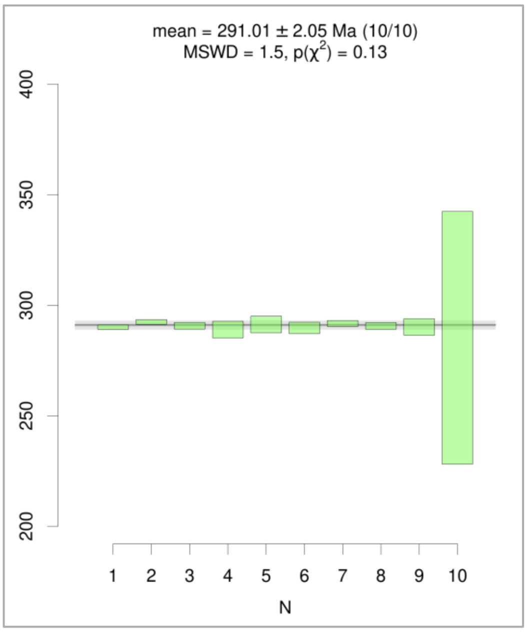
Granite g_IDN#5: muscovite of this evolved granite facies (G4) provided a very disturbed heating spectrum from which only a total fusion age of 379.6 ± 1.9 Ma was calculated.

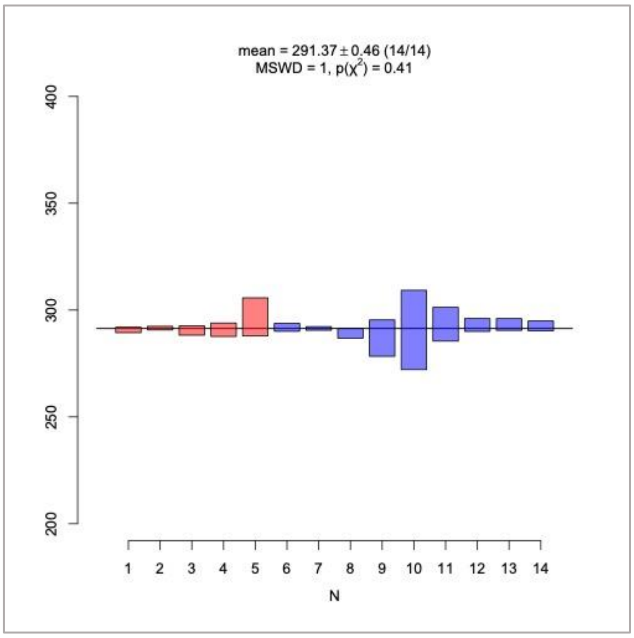


Microgranite gf_IDN#4 (left) and granodiorite g_IDN#6 (right): biotite of these samples provided very consistent WMAs. The age for gf_IDN#4 was calculated with 8 steps at 290.2±2 Ma, while g_IDN#6 has a WMA calculated from the most coherent steps of two grain aliquots at 289.3±0.5 Ma.

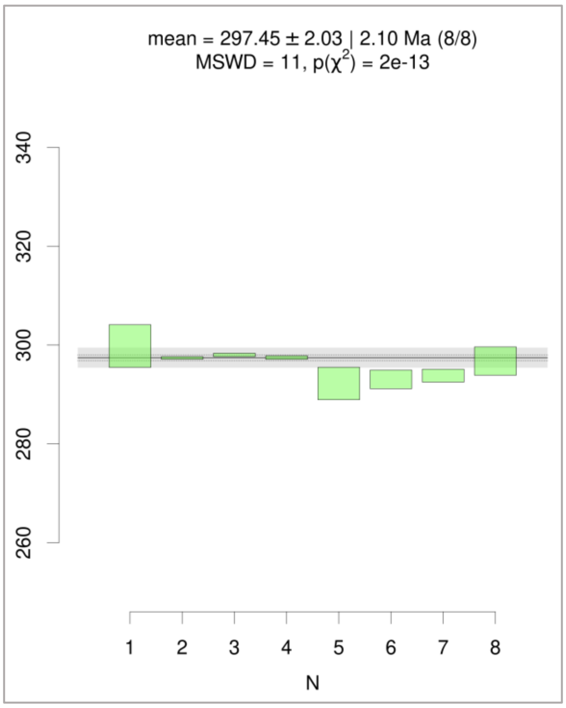
3. PENAMACOR-ORCA site

Five mucovite samples were selected for mica Ar/Ar dating: g_SEIXO#, g_SEIXO#2, gf_MDR#1, gf_STC#1A and gf_STC#1B.

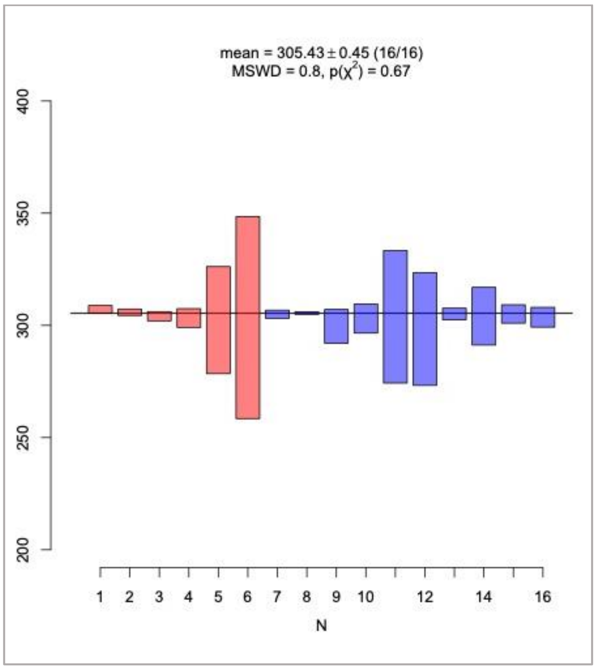


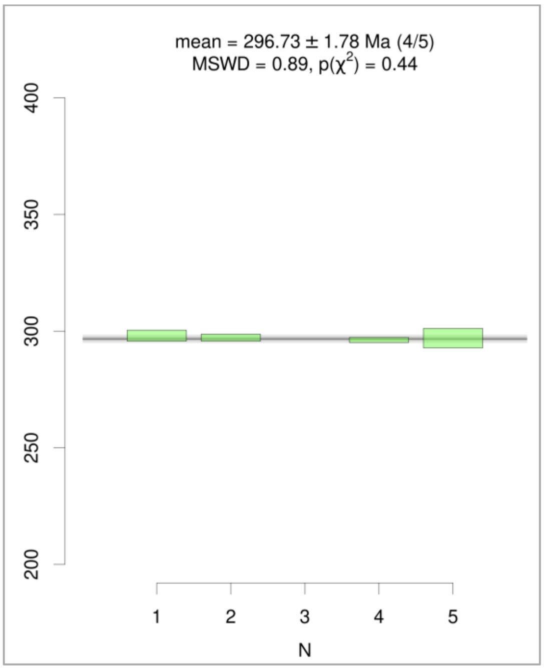


Granite g_SEIXO#1 and g_SEIXO#2: muscovite of the inner granite facies (SEIXO#1) in the Seixoso area provided a plateau age of 291.0±2.1 Ma, while the outer facies (SEIXO#2) of the same granite was dated in 291.4±0.5 Ma calculated from the most coherent steps of two grain aliquots. These Ar/Ar ages were quite younger than the U-Pb zircon Concordia ages obtained for the same samples of the granite.



Vein gf_MDR#1: muscovite extracted from a mineralized vein (salbanda) in the Mata da Rainha area yielded a WMA of 297.5±2.0 Ma calculated with 8 steps.

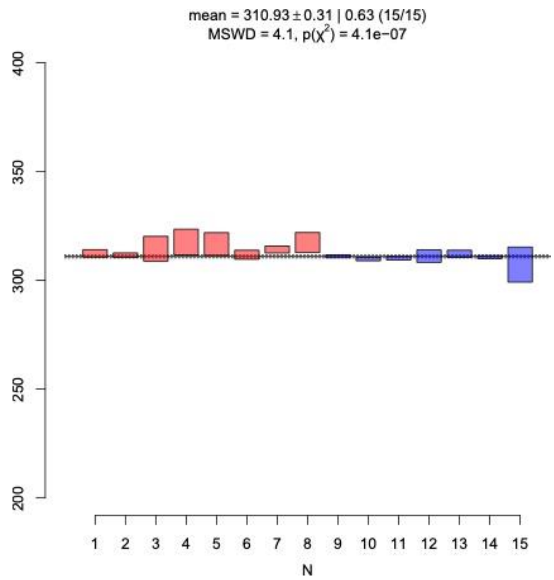


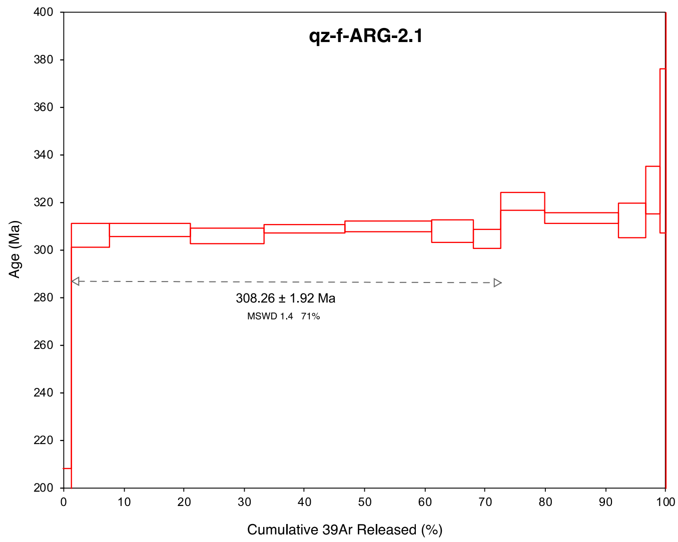


Pegmatite gf_STC#1A and aplite gf_STC#1B: muscovite of a pegmatite (gf_STC#1A) and an aplite vein (gf_STC#1B) of the Santa Catarina area provided, respectively, WMAs of 305.4±0.5 Ma and 296.7±1.8 Ma. For the latter, the WMA was calculated using only for heating steps.

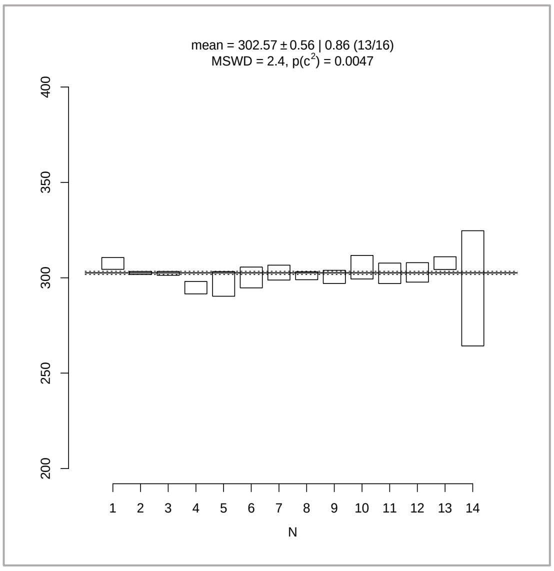
4. ARGEMELA site

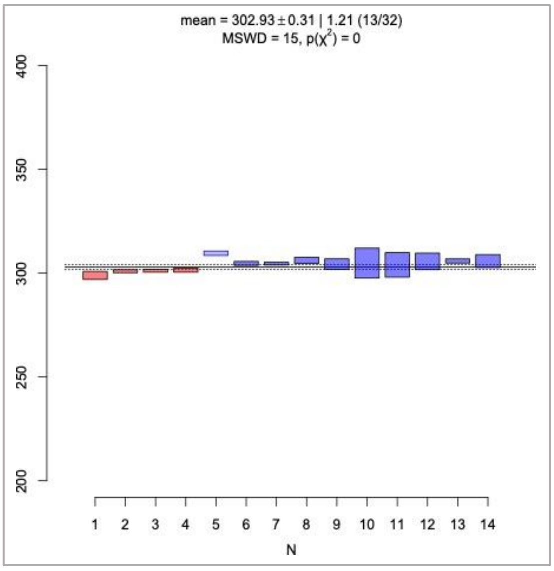
All four Ar/Ar ages of this site came from muscovite grains extracted either of granites (g_ARG#1 and qz-f_ARG#2) or aplite veins (gf_ARG#4 and gf_ARG#5).





Aplite gf_ARG#5 and granite qz-f_ARG#2: the ages obtained from muscovite of these samples are quite similar at 310-308 Ma. The aplite yielded a WMA at calculated from two aliquots at 310.9±0.3 Ma, while the granite provided a plateau age of 308.3±1.9 Ma.

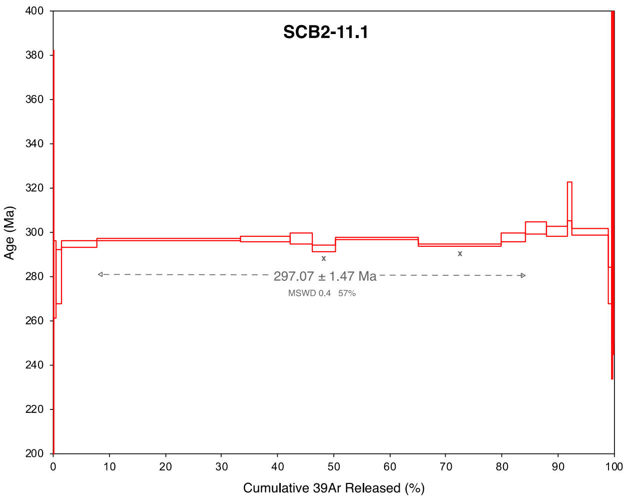


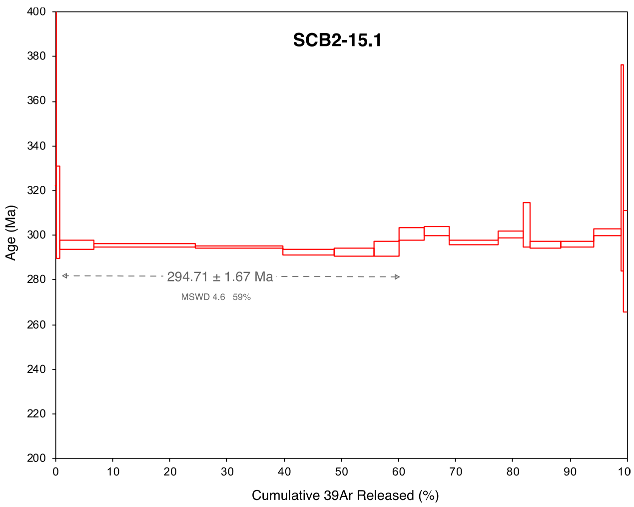


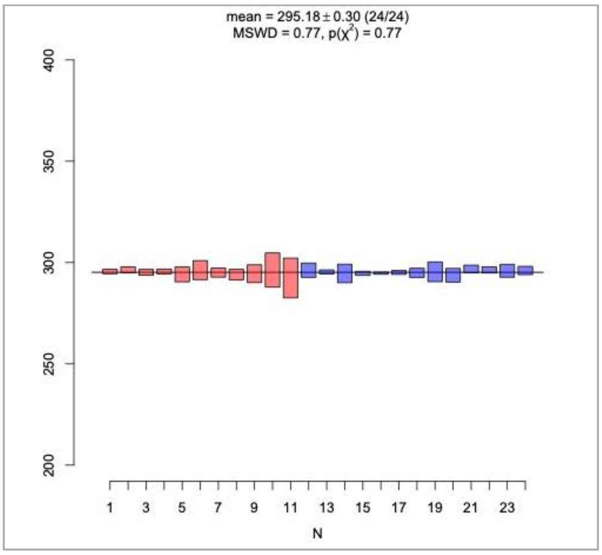
Granite g_ARG#1 and aplite gf_ARG#4: the WMAs obtained from muscovite of these samples were equal at 302.6±0.6 Ma and 302.9±0.3 Ma, respectively.

5. PANASQUEIRA site

When considered the inidvidual analytical uncertainties of each muscovite of the Panasqueira site, the ages are similar. Muscovite of two granites sampled from well logs – SCB#11 and SCB#15 are, respectively, 297.1±1.5 Ma and 294.7±1.7 Ma, while the WMA calculated with two grain aliquots of the sample P11_g (a greisen) perfectly overlap them at 295.2±0.3 Ma. The Ar/Ar age of SCB#11 (a 2-mica granite) is a little younger than a U-Pb Concordia age of 303.6±5.8 Ma obtained from zircon grains of this sample. However, the high imprecision of the U-Pb age makes it an unreliable age for crystallization.

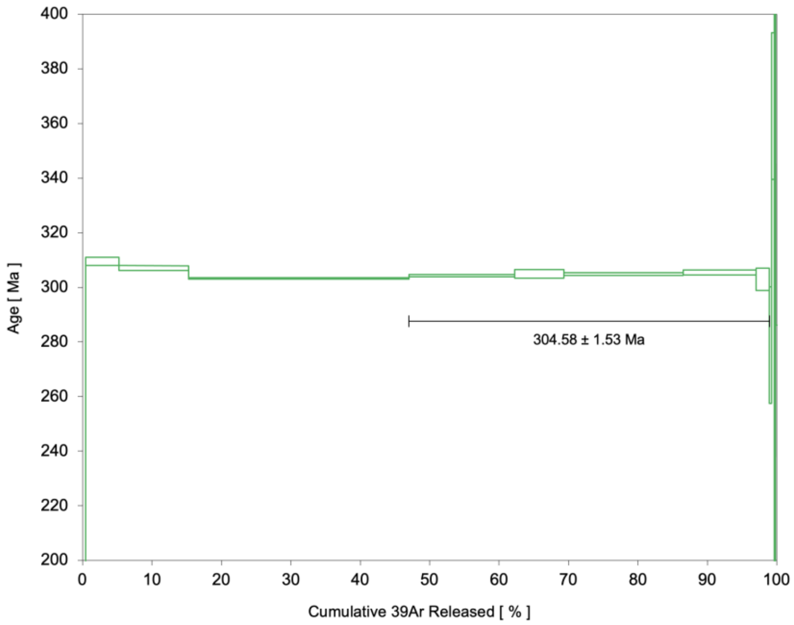




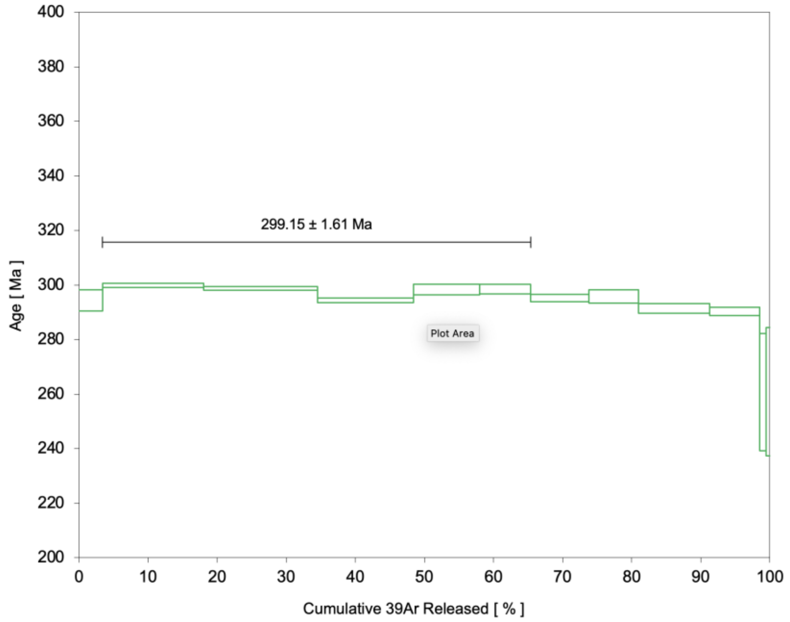


6. MONSANTO site

Four muscovite and one biotite were analysed for Ar/Ar dating. They were extracter from a granite (g_MONS#2), a metassomatized facies of this granite (g_MONS#1), a pegmatite(g_MONS#1A) and a quartz vein (VT.MONS#1B). When ordering by their respective U-Pb and Ar/Ar ages, the granite has a zircon age of 311.2±2.8 Ma with a Ar/Ar (plateau age) muscovite of 304.6±1.5 Ma and a Ar/Ar biotite of 299.2±1.6 Ma. In spite of a plateau with 53% 39Ar, the age of the muscovite could be a little younger if the D-step (32% 39Ar; apparent age of 303.3 Ma) is included in the (WMA) calculation. Also, alternative WMA calculations for the biotite are possible if other steps are included.

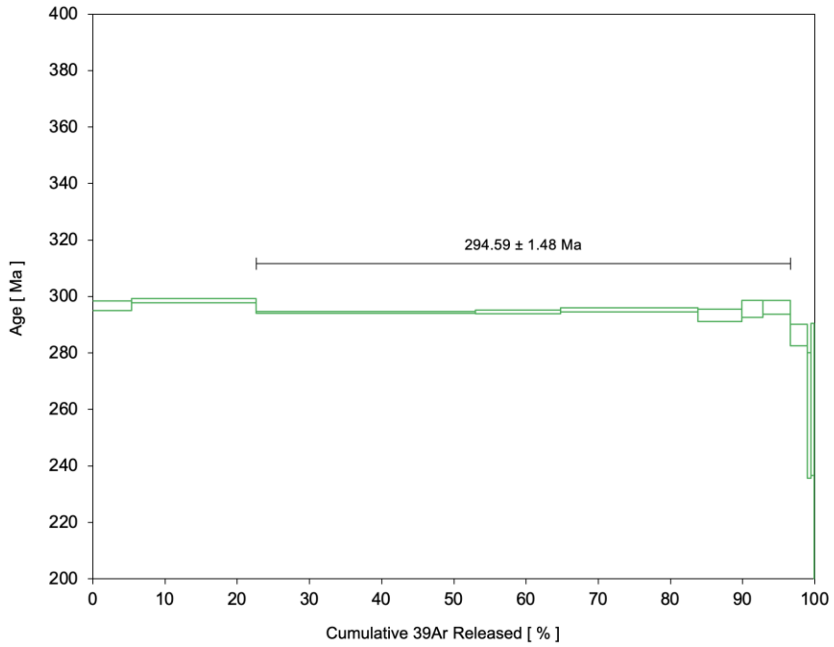


Muscovite of g_MONS#2



Biotite of g_MONS#2

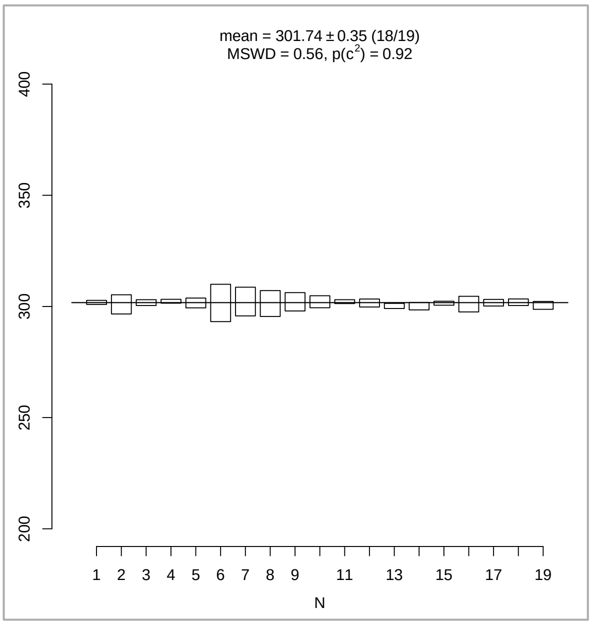
The muscovite of the metassomatized facies of the granite g_MONS provided a plateau age of 294.6±1.5 Ma, which is only a bit younger than the best estimate WMA obtained for the muscovite collected from the quartz vein (VT.MONS#1B) cutting the granite – 297.4±1.6 Ma. As shown below, the heating spectrum for such muscovite aliquot was quite disturbed, with only 5 steps used for calculation of the WMA age (the x-step were excluded).



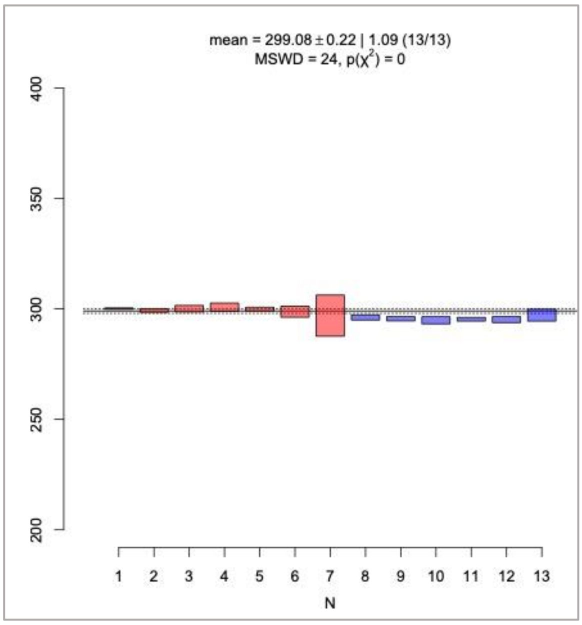
Muscovite of g_MONS#1
(metassomatized facies)

7. MEDELÍN site

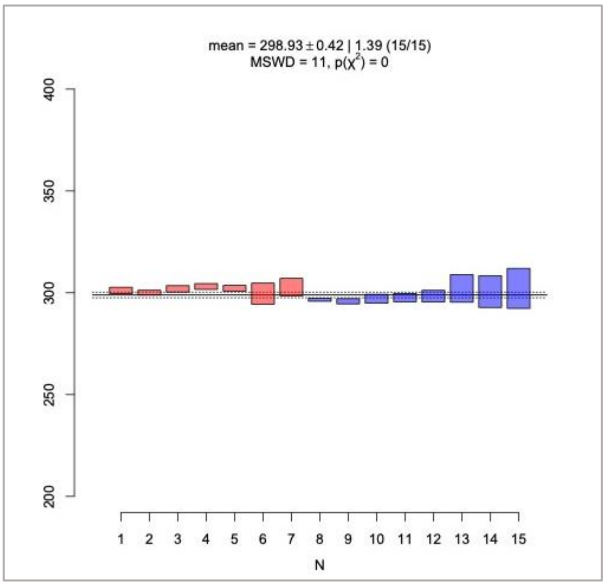
Muscovite of three samples were analyzed and provided very similar WMAs. The muscovite of the evolved facies of the granite was dated at 301.7±0.4 Ma, an age a little older than the ages obtained for muscovite from the outer facies of this granite and from an aplite vein, respectively at 298.9±0.4 Ma and 299.1±0.2 Ma.



Evolved facies g_MED#1



Outer facies g_MED#2



Aplite vein gf_MED#1