CRONUS Results: An interhemispheric Workshop

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^{36}Cl spallation production rate calibration from Ca and K in lava flows

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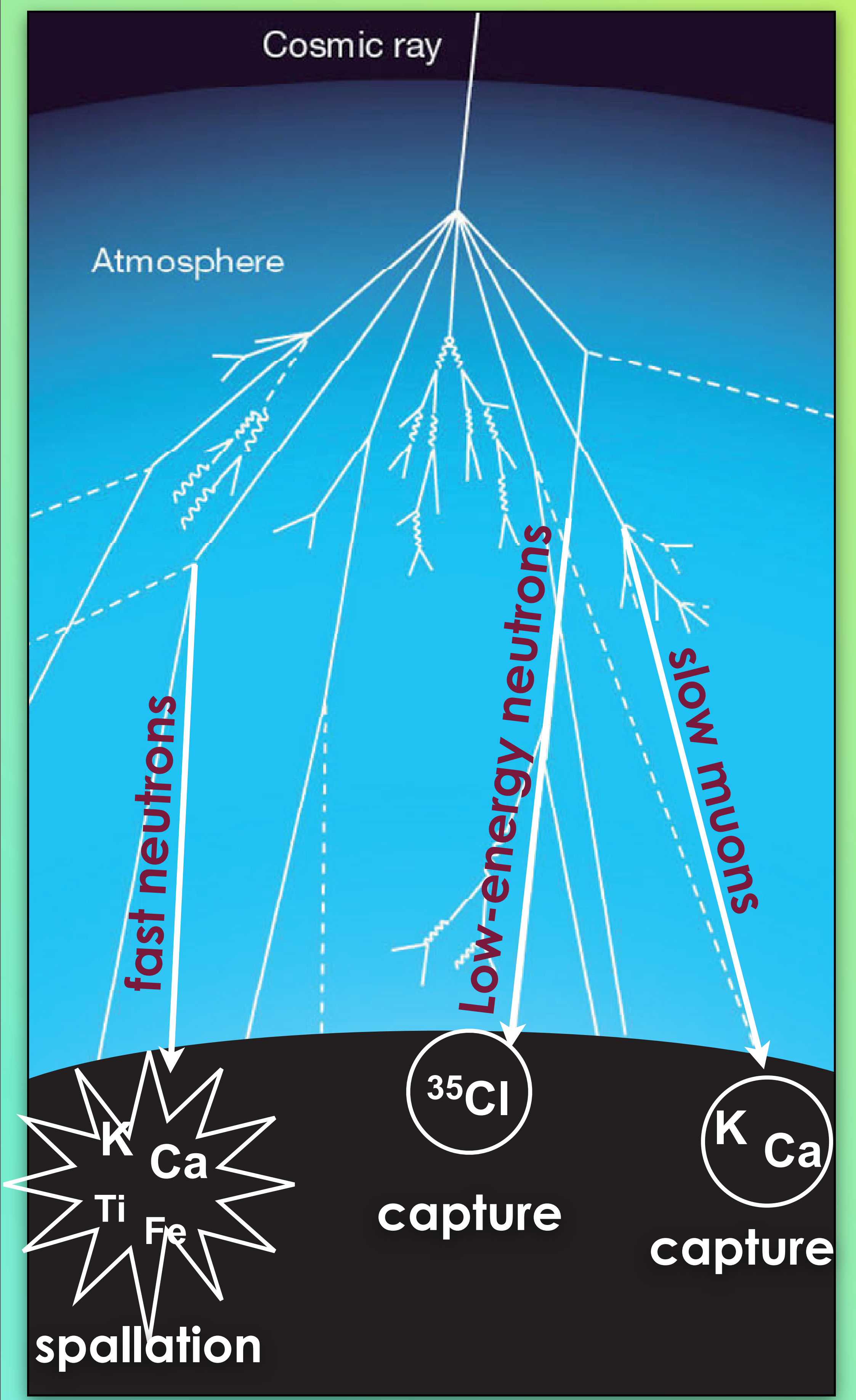
Cosmogenic in-situ ^{36}Cl production mechanisms:



- **Fast neutrons:** Spallation of target elements Ca, K, (Ti, Fe)
- **Low-energy (thermal and epithermal) neutrons**: Capture by ^{35}Cl
- **Slow negative muons:** Capture by Ca and K

$$[^{36}Cl]=(P_s + P_n + P_\mu)\ t_{expo}$$

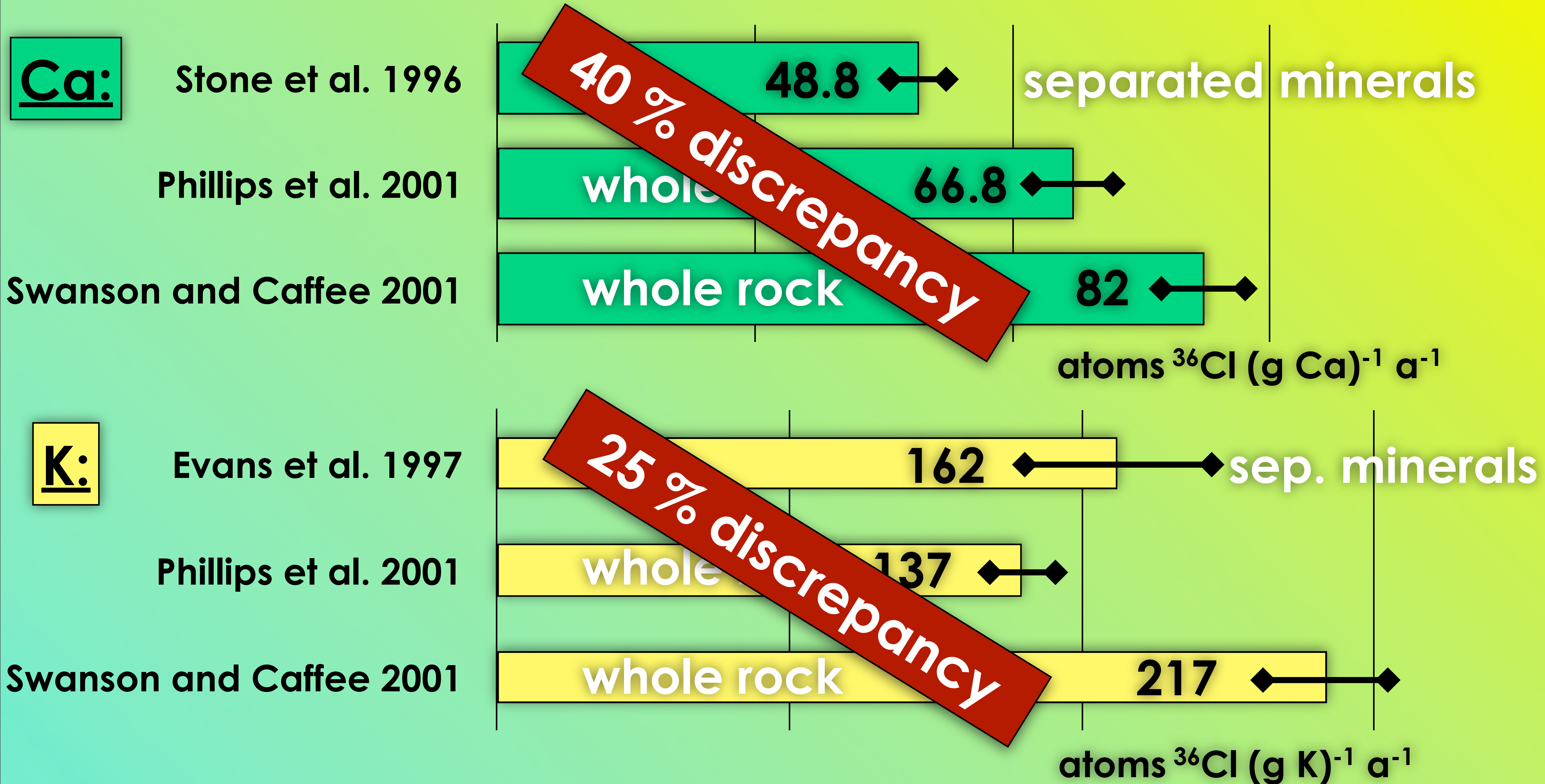
spallation

low-energy neutrons

slow muons

exposure time

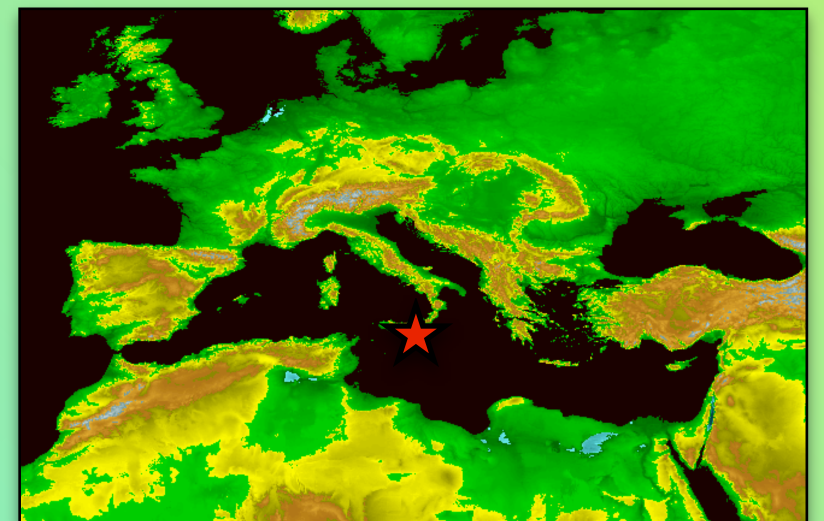
^{36}Cl spallation production rates (SLHL)



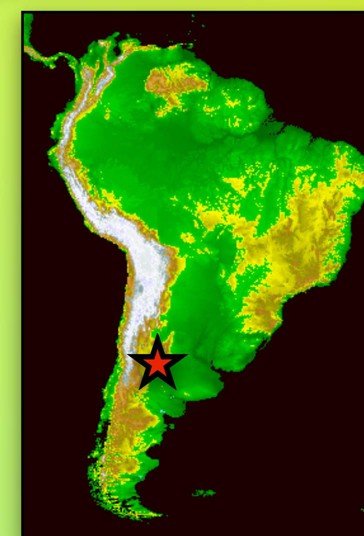
I. Track ^{36}Cl in whole rock and separated minerals
II. ^{36}Cl production rate calibration for spallation of Ca and K

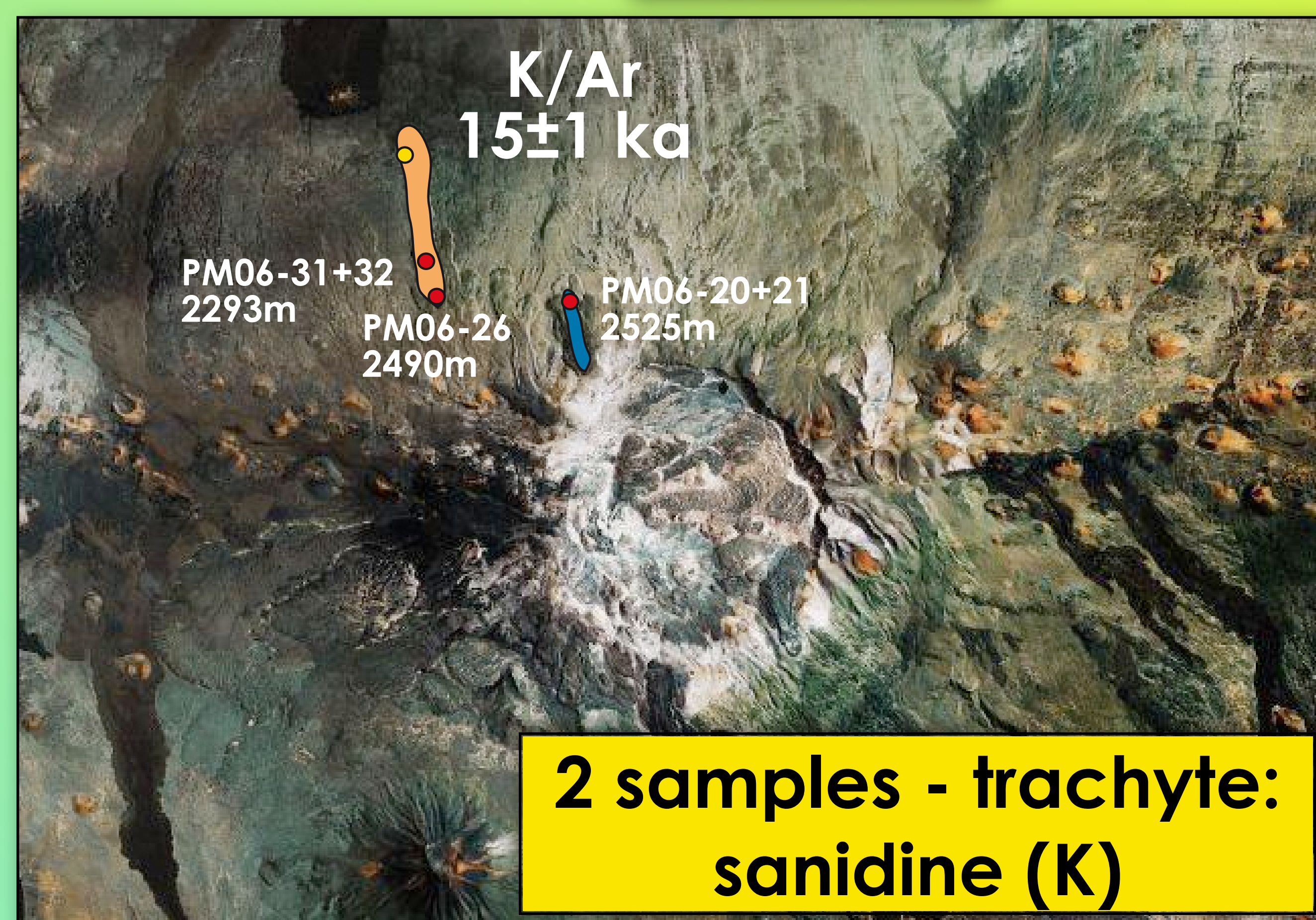
Calibration sites

Mt. Etna (Sicily, 38°N)



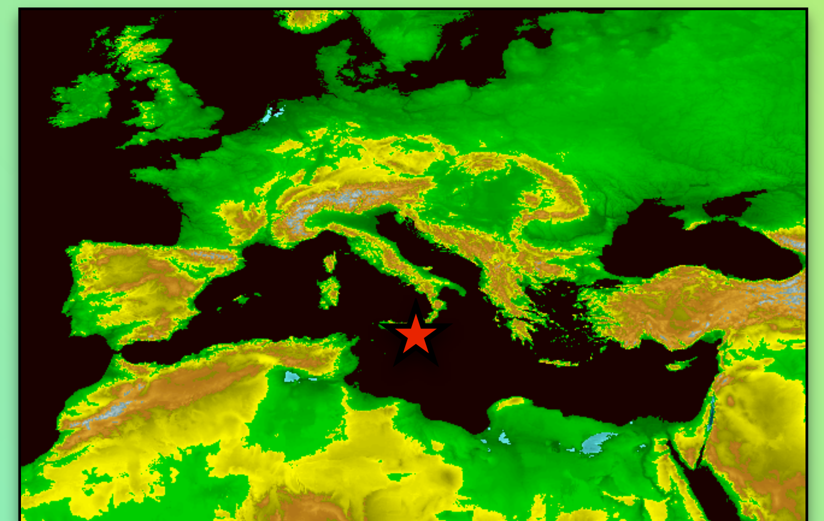
Payun-Matru (Argentina, 36°S)

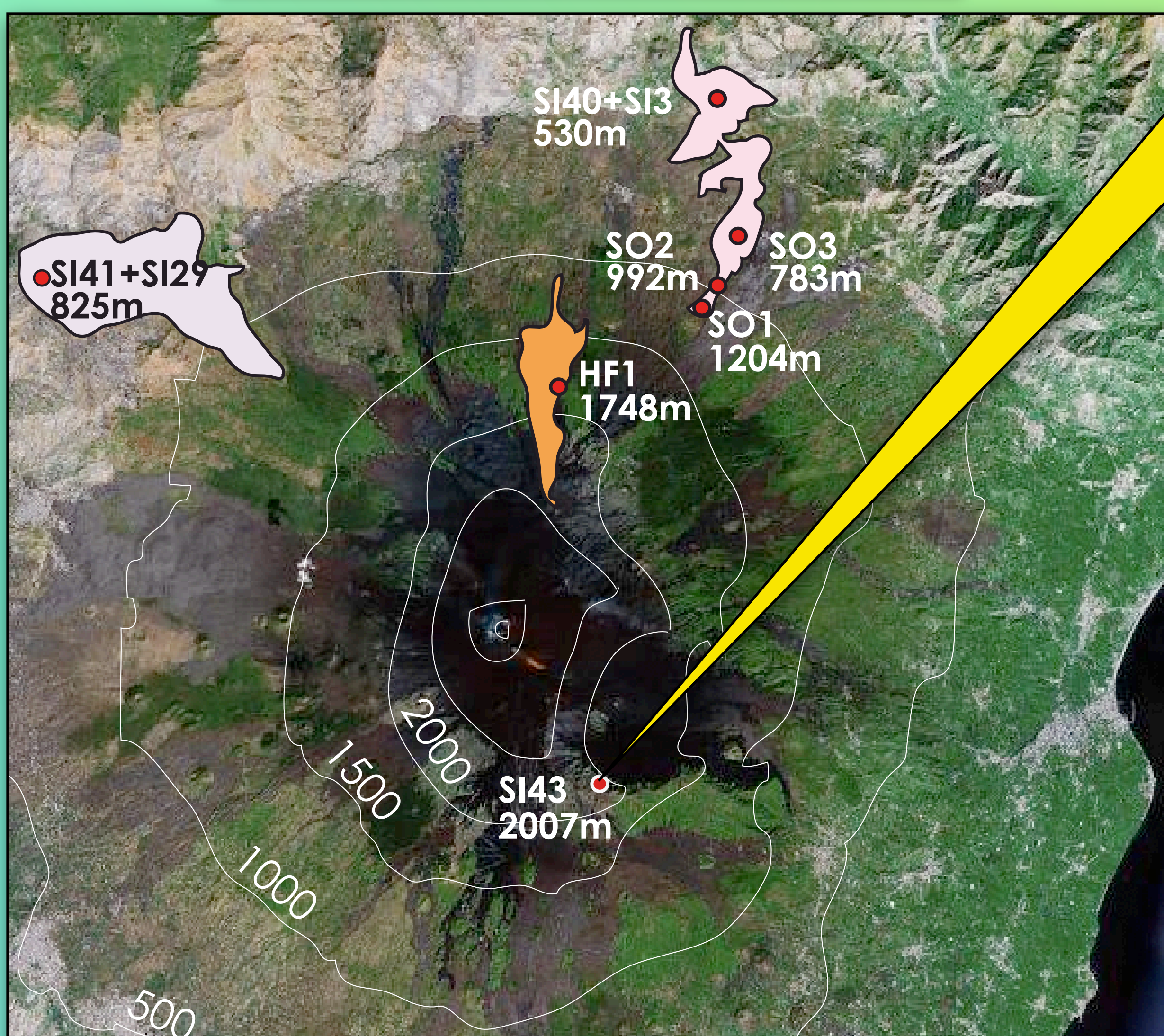




Tracking ^{36}Cl in whole rock and separated minerals

Mt. Etna (Sicily, 38°N)

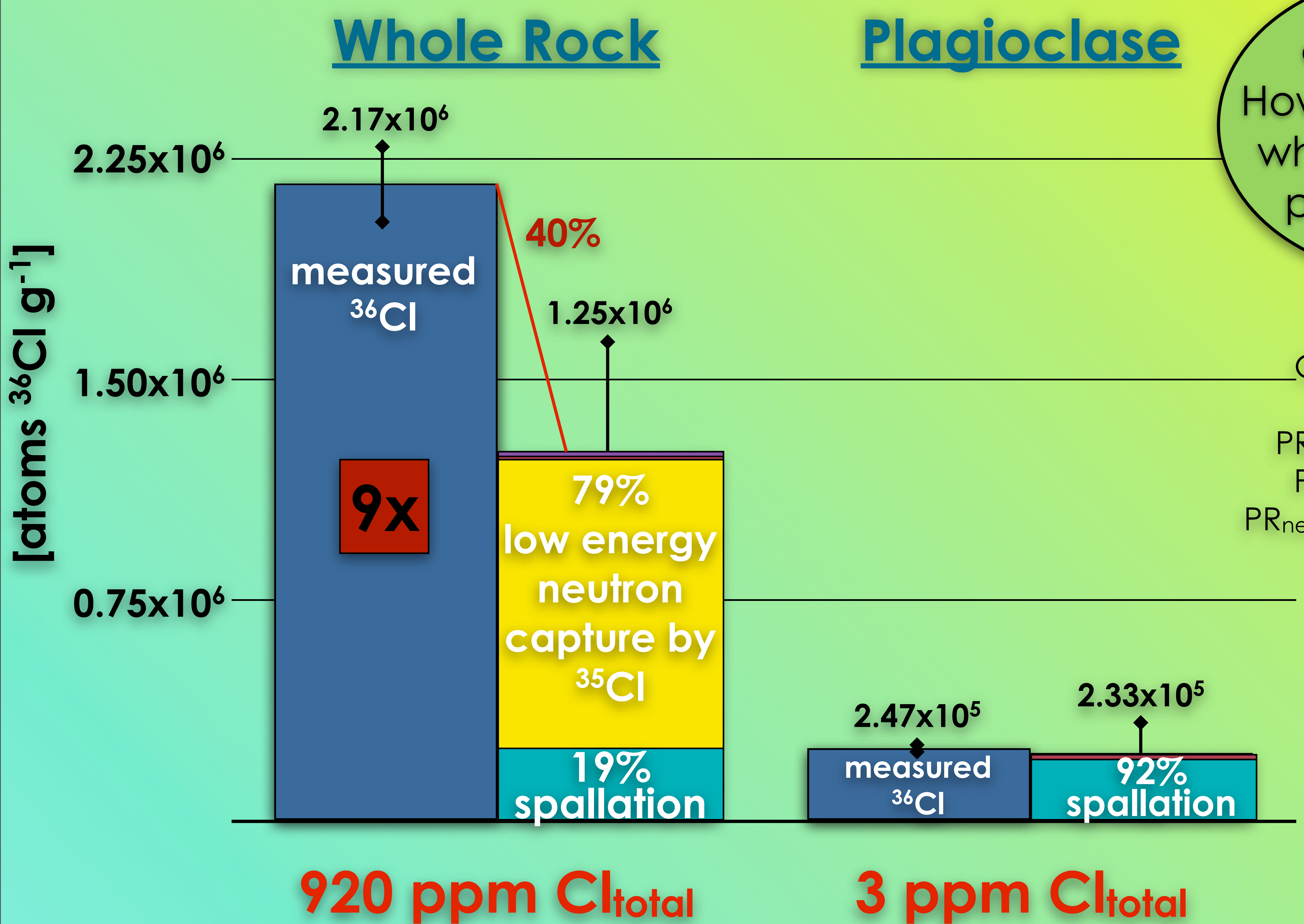




SI43:

- abundant Ca-plagioclase phenocrysts
- exposure age: 10±3 ka (K/Ar)
- ^{3}He exposure age (pyroxene phenocrysts): 9.6±0.9 ka

Comparison:
Whole Rock and Plagioclase



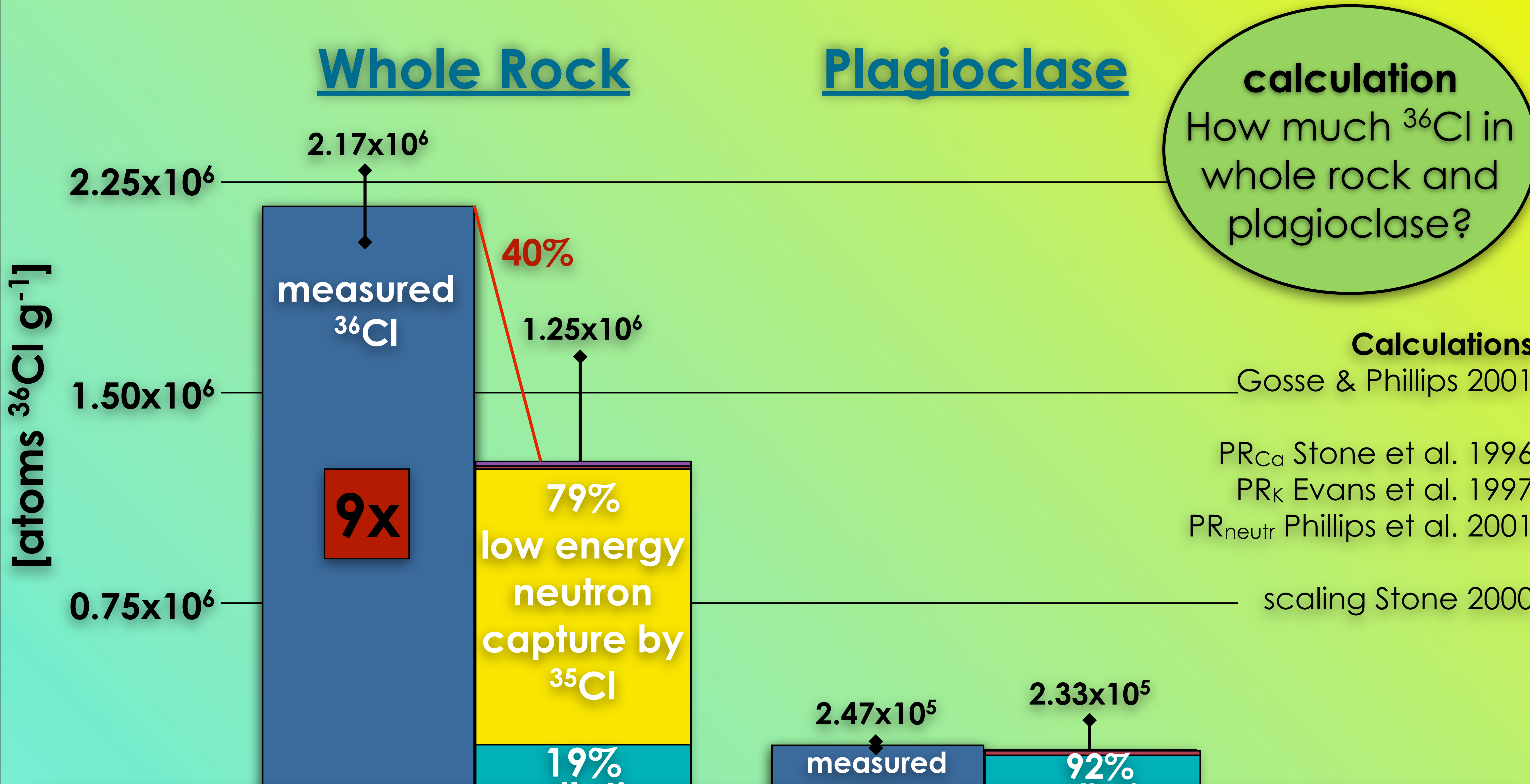
calculation
How much ^{36}Cl in whole rock and plagioclase?

Calculations
Gosse & Phillips 2001

PR_{Ca} Stone et al. 1996
PR_{K} Evans et al. 1997
PR_{neutr} Phillips et al. 2001

scaling Stone 2000

Comparison: Whole Rock and Plagioclase



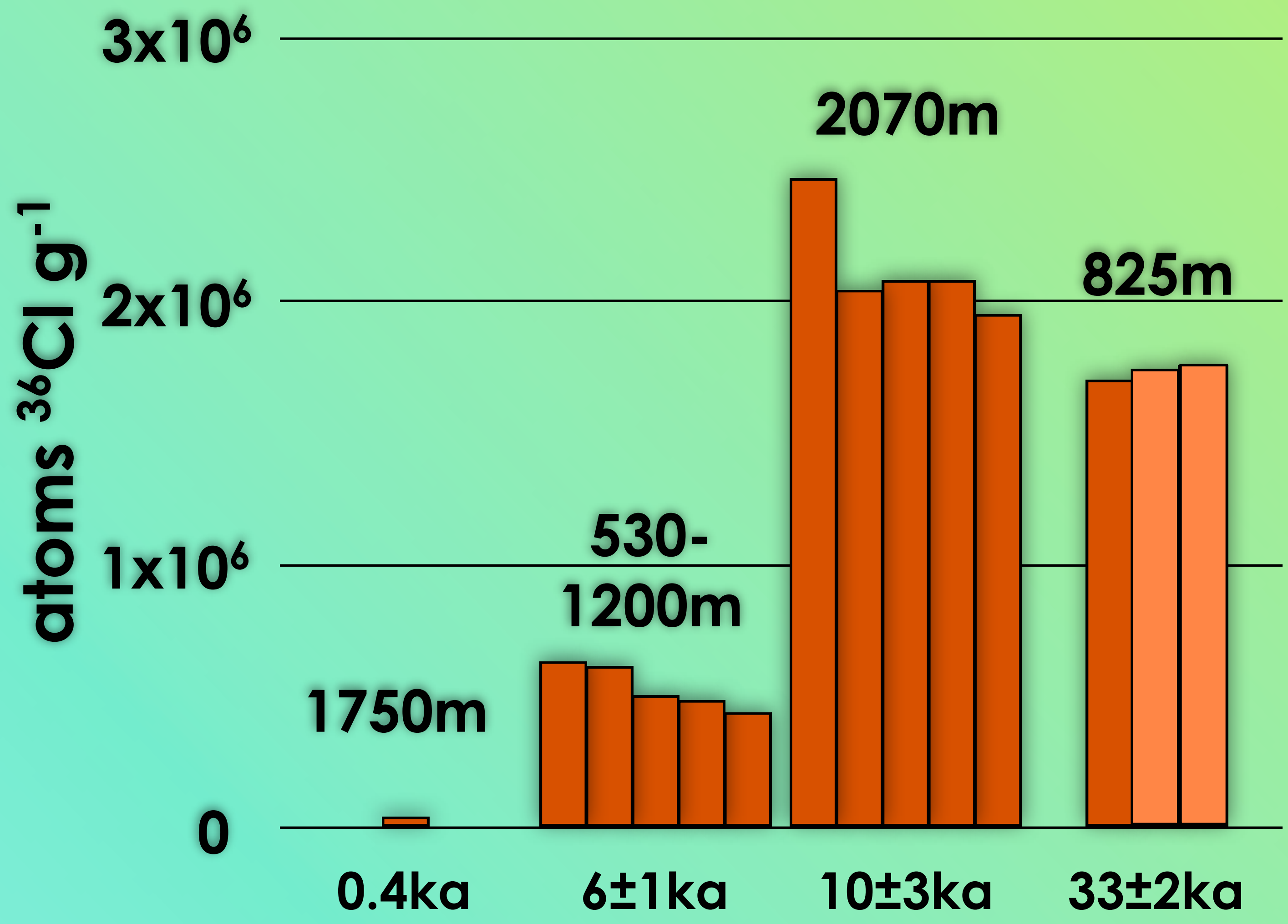
underestimation of ^{36}Cl production ➡ complex behaviour of low-energy neutrons at land/atmosphere boundary

^{36}Cl production rate calibration for spallation of Ca and K

Mt. Etna

Ca rich plagioclase

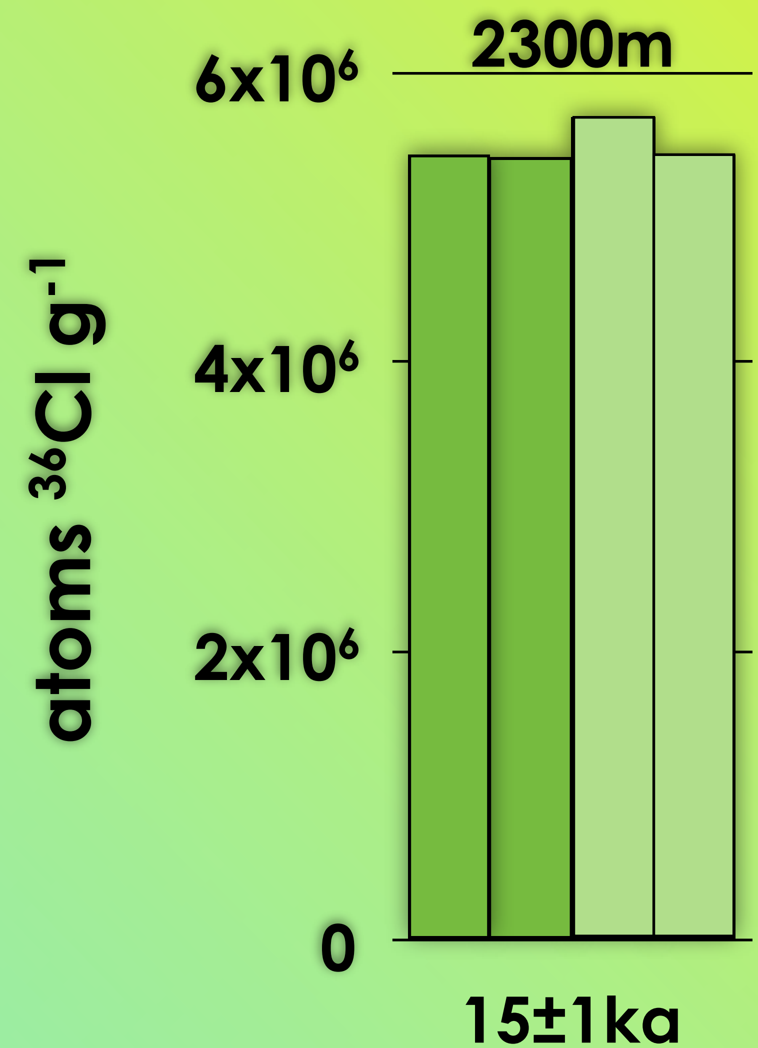
[Ca] = 7.1 - 8.9%
[K] = 0.3 - 0.5%
[Cl_{total}] = 1-6 ppm



Payun-Matru

sanidine (K)

[Ca] = 0.6%
[K] = 5.4%
[Cl_{total}] = 8-13 ppm



Production rate determination

measured ^{36}Cl concentration

chemical composition

calculation
spallation production rates from Ca and K

independent age
(+ radioactive decay
+ erosion)

$$\frac{1 - exp^{-(\lambda_{36}+\rho\varepsilon/\Lambda)t_{indep}}}{\lambda_{36}+\rho\varepsilon/\Lambda}$$

correction factors:
scaling
thickness
shielding
geometry

? ?

$$[^{36}Cl]_{meas} = (F_s([Ca]\ PR_{Ca} + [K]\ PR_K) + F_n P_n + F_\mu P_\mu)\ t_{indep}$$

spallation

low-energy neutrons

slow muons

$$[^{36}Cl] = (P_s + P_n + P_\mu)\ t_{expo}$$

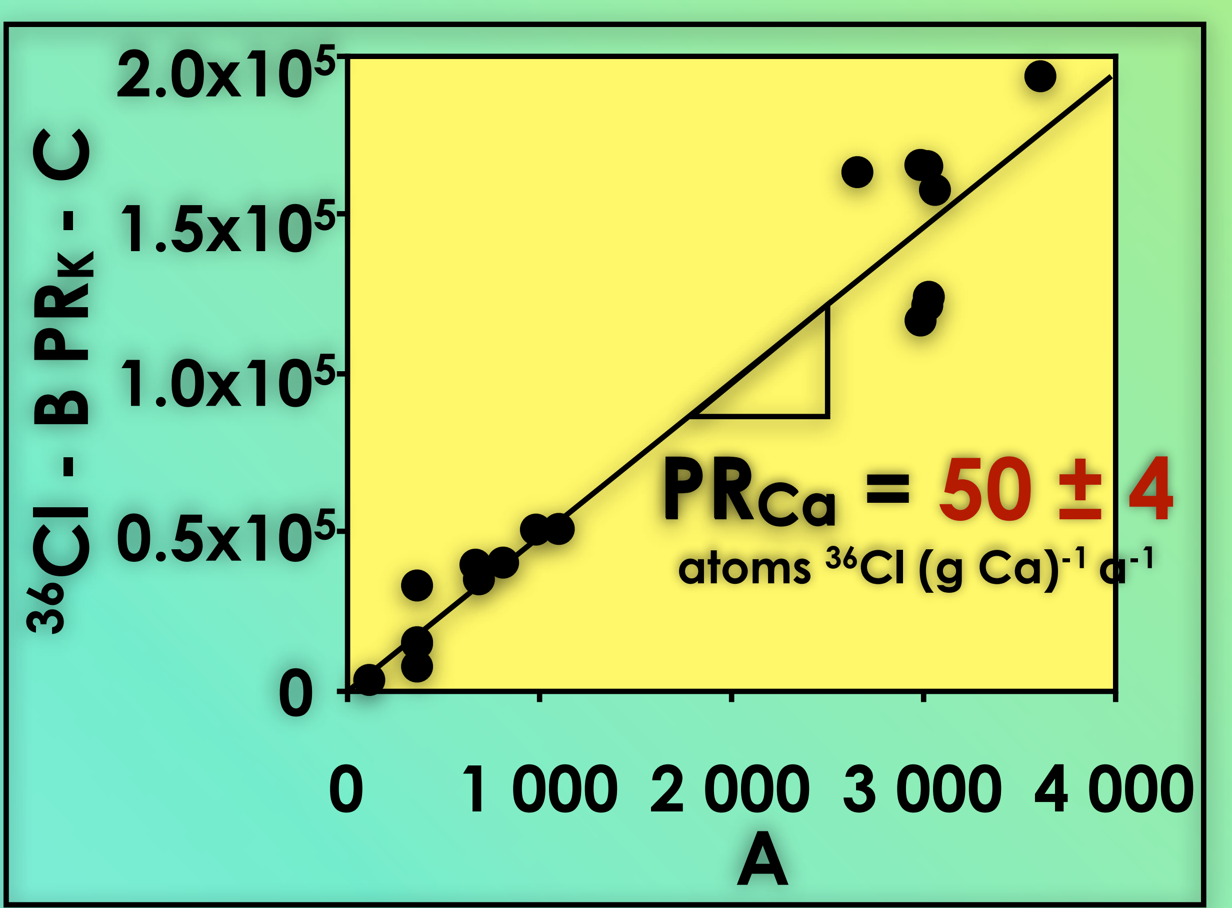
Production rate determination

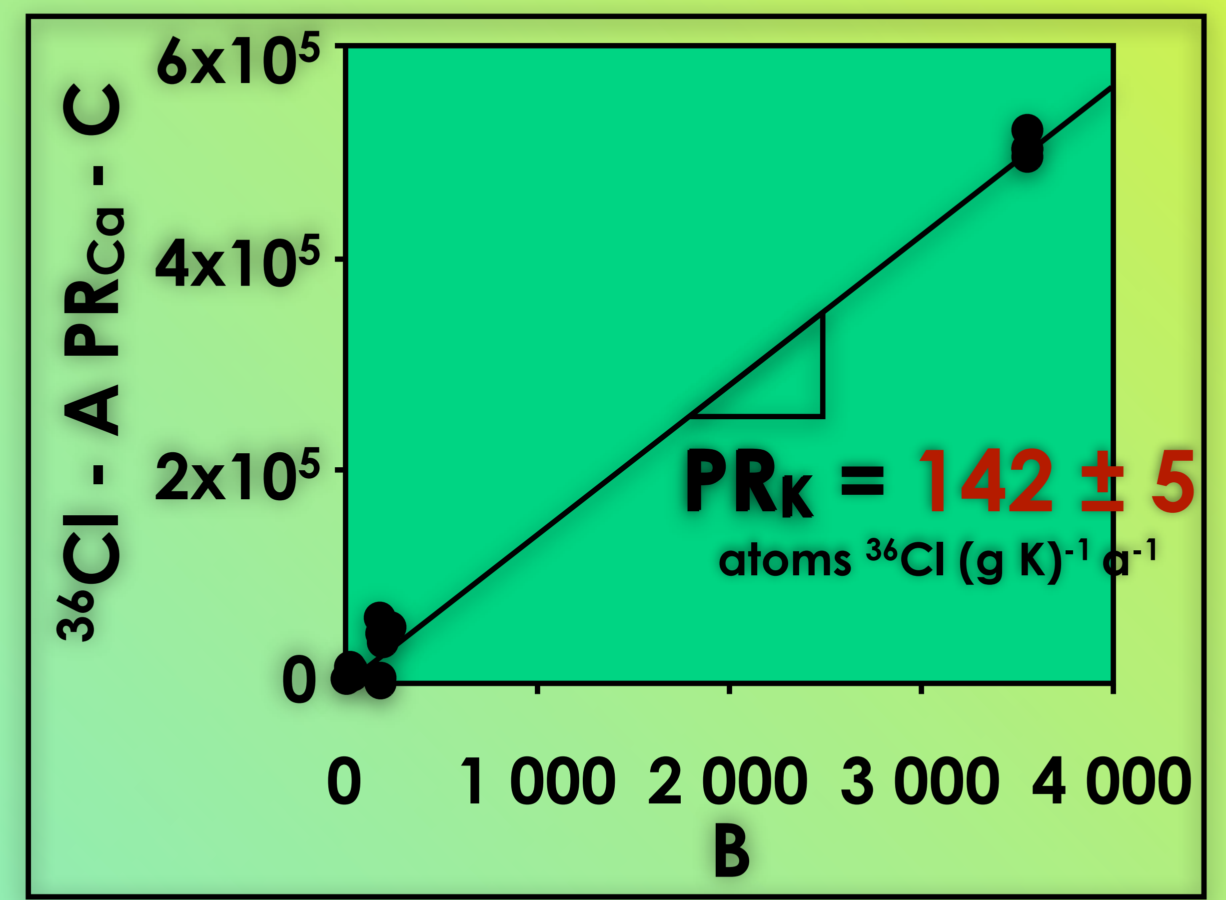
$$[^{36}Cl]_{meas} = (F_s\,([Ca]\,PR_{Ca} + [K]\,PR_K) + F_n\,P_n + F_\mu\,P_\mu)\,t_{indep}$$

2 statistic methods:

1. "Best fit" linear model (least square)

$$[^{36}Cl]_{meas} = A\,t\,PR_{Ca} + B\,t\,PR_K + C\,t + \Delta$$





Production rate determination

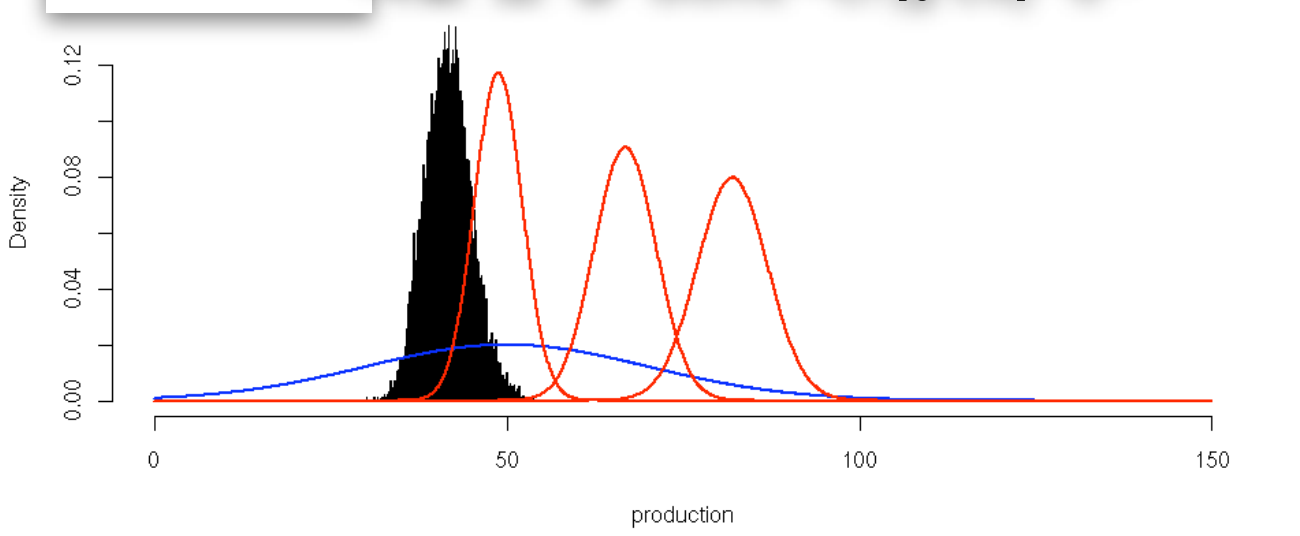
$$[^{36}Cl]_{meas} = (F_s\,([Ca]\,PR_{Ca} + [K]\,PR_K) + F_n\,P_n + F_\mu\,P_\mu)\,t_{indep}$$

2 statistic methods:

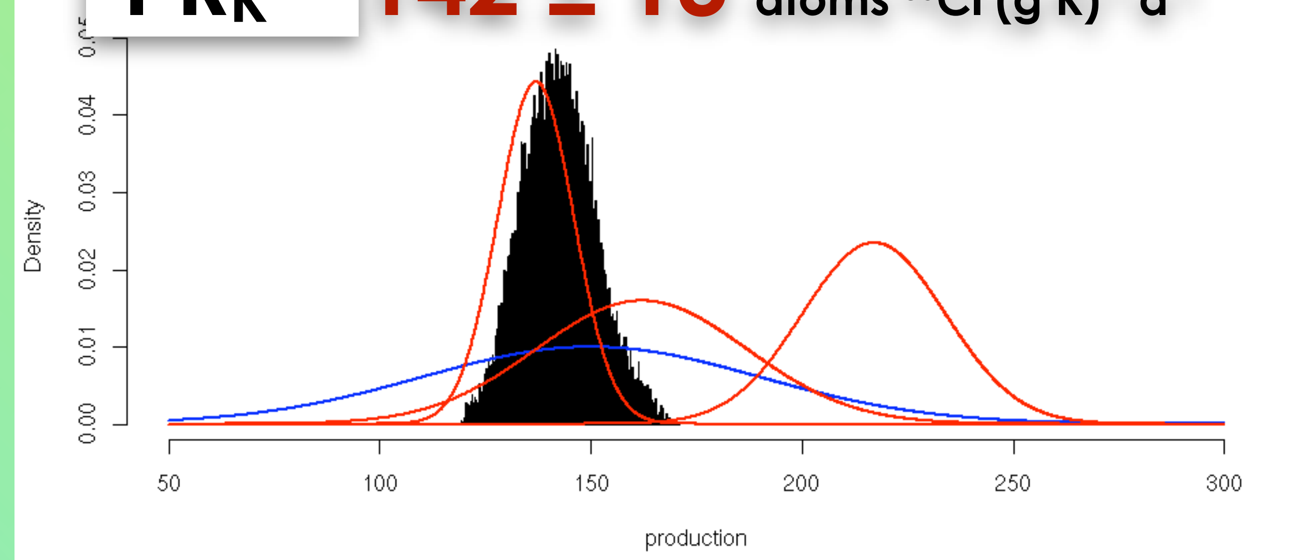
2. Nonlinear mixed model (MCMC - Bayesian)

$$[^{36}Cl]_{meas} = A\,(t + \Delta_F)\,PR_{Ca} + B\,(t + \Delta_F)\,PR_K + C\,(t + \Delta_F) + \Delta$$

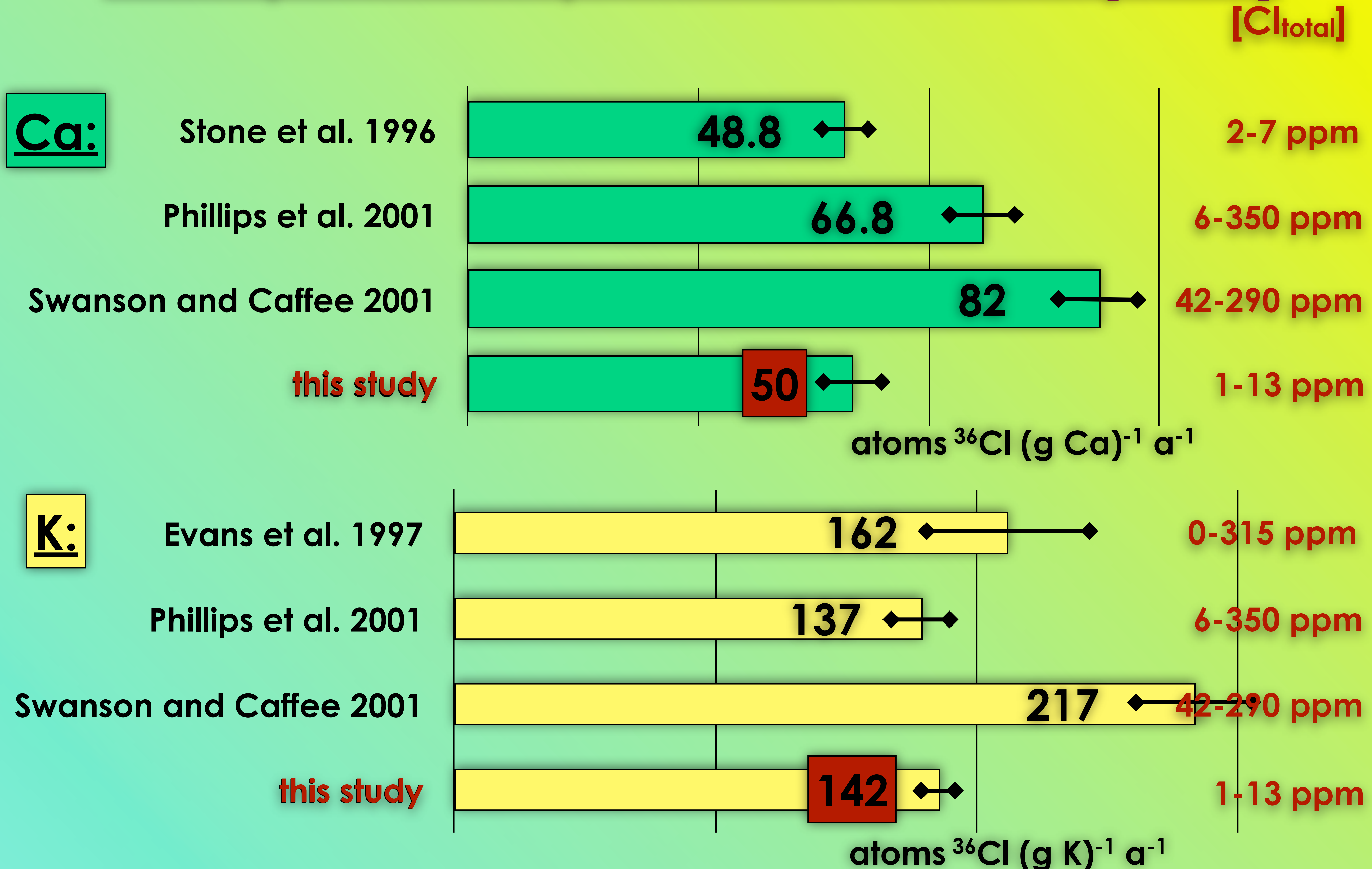
PR_{Ca} = **42 ± 5** atoms $^{36}Cl\ (g\ Ca)^{-1}\ a^{-1}$



PR_K = **142 ± 13** atoms $^{36}Cl\ (g\ K)^{-1}\ a^{-1}$



^{36}Cl spallation production rates (SLHL)



high Cl_{total} contents ➡ overestimation of spallation production rates???

Conclusions

✱ calculations of 36Cl production due to low-energy capture very uncertain ➡ avoid Cl-rich samples

✱ spallation production rates - from simple linear model:

PR_{Ca} = 50 ± 4 atoms ^{36}Cl (g Ca)$^{-1}$ a^{-1}

PR_{K} = 142 ± 5 atoms ^{36}Cl (g K)$^{-1}$ a^{-1}

✱ spallation production rates - from non-linear mixed model:

PR_{Ca} = 42 ± 5 atoms ^{36}Cl (g Ca)$^{-1}$ a^{-1}

PR_{K} = 142 ± 13 atoms ^{36}Cl (g K)$^{-1}$ a^{-1}

✱ input 3 more sanidine (K) samples