^{26}Al-^{10}Be exposure age/erosion rate calculators: update from v. 2.1 to v. 2.2

The update to version 2.2 was effective March 19, 2009.

Note: The list of AMS standards that originally appeared as Tables 2 and 3 at the end of this document has been extensively updated since this date. As of November 1, 2010, these tables now appear as a separate document.

Also note that some of the constants described in this document have been further updated. These changes are described in a separate document describing the update of the constants file to version 2.2.1.

Questions on this document: Greg Balco, *balcs@u.washington.edu*

1 Summary

This describes changes between versions 2.1 and 2.2 of the CRONUS-Earth online ^{26}Al-^{10}Be exposure age and erosion rate calculators. These changes are prompted by the remeasurement of Be isotope ratios in a commonly used Be standard material by Nishiizumi et al. (2007). They include: i) a revised value for the ^{10}Be decay constant; ii) renormalization of reference ^{10}Be production rates; and iii) a new requirement that calculator users specify how their ^{10}Be and ^{26}Al measurements were standardized.

1.1 Background

^{10}Be concentrations in geological quartz samples are measured by an isotope-dilution method in which one adds a measured quantity of ^{9}Be to a measured weight of quartz, dissolves the quartz, extracts Be from the resulting solution, and measures the ^{10}Be/^{9}Be ratio by accelerator mass spectrometry (AMS). Given that the natural ^{9}Be concentration in the quartz is negligible, one then calculates the ^{10}Be concentration from the amount of added ^{9}Be and the measured isotope ratio. The AMS technique does not directly measure the absolute isotope ratio of the sample Be, but compares its isotope ratio to that of a Be reference material whose absolute isotope ratio has been measured independently. Thus, the accuracy of a ^{10}Be concentration measurement depends entirely on the accuracy of the absolute isotope ratio assumed for the reference material.

There are several ^{10}Be-enriched stocks of Be, each accompanied by a defined isotope ratio, from which the reference materials used in AMS measurements have been derived. I will refer to one of these stocks of Be and its derivatives as a 'standard material.' Several AMS facilities have compared isotope ratios of these standard materials and shown that their defined isotope ratios are inconsistent. In addition, several AMS facilities have at various times tried to correct for these inconsistencies by using a particular Be standard material, but assuming that it has an isotope ratio different from the ratio originally defined for that standard material. Thus, ^{10}Be measurements made at different AMS facilities, or at different times at the same facility, are often inconsistent. Also, this practice means that defining how a particular AMS measurement was standardized requires two pieces of information: the name of the physical standard material itself, and the isotope ratio that it is assumed to have. I will refer to a standard material/assumed isotope ratio pair as a 'standardization.'

One commonly used Be isotope ratio standard material is that manufactured by Nishiizumi (Nishiizumi, 2002). This material, with an isotope ratio defined by Nishiizumi at the time of manufacture, was widely used at many AMS facilities. This standard material is commonly known as the 'KNSTD' or 'ICN' standard material. The KNSTD/ICN standard material with the isotope ratios defined by Nishiizumi (2002) is herein known as the KNSTD standardization.

In an effort to reconcile inconsistencies among Be standardizations, Nishiizumi et al. (2007) remeasured the absolute isotope ratio of the KNSTD/ICN standard material using a new technique. They found that the previously assumed isotope ratio was incorrect, and defined a new isotope ratio for the KNSTD/ICN standard material. A new standardization, consisting of the same standard material with the revised isotope ratio, is now in use at many AMS facilities. Here we refer to this as the '07KNSTD' standardization. In addition, Nishiizumi et al. (2007) compared the isotope ratio of the KNSTD/ICN standard material with the isotope ratios of other standard materials. This yielded a set of conversion factors that could be used to correct Be isotope ratios measured using these other standard materials to be consistent with the 07KNSTD standardization. Finally, one commonly used value of the ^{10}Be decay constant had been determined by decay counting of the same stock of Be used to manufacture the KNSTD/ICN standard material. A revision in the absolute isotope ratio of that standard material implies a revision in the ^{10}Be decay constant. Thus, Nishiizumi et al. (2007) also revised the ^{10}Be decay constant to be $5.10 \pm 0.26 \times 10^{-7}$ yr^{-1}.

1.2 Importance

The importance of these results for exposure dating and erosion rate measurements with ^{10}Be is as follows.

First, in calculating exposure ages at sites whose exposure age is short relative to the ^{10}Be half-life, or erosion rates at rapidly eroding sites, if ^{10}Be concentrations were measured using the now obsolete KNSTD standardization *and* production rates were computed from calibration measurements made in the same way, then the errors that arise from the incorrect isotope ratio assumed in the KNSTD standardization cancel each other, and there is a minimal effect on the exposure age. However, this is not the case for long exposure times or low erosion rates, when the duration of surface exposure is comparable to the ^{10}Be half-life. In these cases, the revision in the ^{10}Be decay constant has a significant effect on the results.

Second, the set of comparisons between the KNSTD/07KNSTD standard material and other commonly used standard materials makes possible a comprehensive and internally consistent conversion between ^{10}Be measurements made against various standardizations. This makes it easier to use the online calculators by removing the necessity for users to renormalize their data offline, and reduces the possibility for errors in this process.

With regard to ^{26}Al, the situation is similar in that there are multiple Al isotope ratio standard materials in use whose defined isotope ratios are not consistent with each other (Nishiizumi, 2004). This is of less practical importance, because the majority of ^{26}Al measurements have employed a single standardization, that of Nishiizumi (2004), which we refer to here as the 'KNSTD' ^{26}Al standardization. Also, existing measurements of the ^{26}Al half-life are in good agreement. Thus, this update does not affect the ^{26}Al standardization used in the existing online calculators. However, calculator users will also be obligated to enter the Al standardization that was used for ^{26}Al measurements.

1.3 Published documentation superseded

The changes described here mean that parts of the published documentation for the online exposure age calculators (Balco et al., 2008) are now obsolete. The following sections of this document reference the specific parts of that paper that have been superseded.

2 Significant changes

2.1 Updated decay constant for ^{10}Be

Version 2.2 of the online ^{26}Al-^{10}Be exposure age and erosion rate calculators now use a value of $5.10 \pm 0.26 \times 10^{-7}$ yr^{-1} for the ^{10}Be decay constant. This supersedes the value stated in section 2.4.2 of Balco et al. (2008).

2.2 Renormalization of reference ^{10}Be production rates

The ^{10}Be concentrations measured at production rate calibration sites and tabulated in Balco et al. (2008) were normalized to the KNSTD standardization. Renormalizing these measurements to the 07KNSTD standardization also changes the values of reference ^{10}Be production rates derived from these calibration measurements. These new values are shown in Table 1. They supersede the values for the reference ^{10}Be production rate due to spallation in Table 6 of Balco et al. (2008).

Note that this also revises the ^{26}Al/^{10}Be production ratio to be 6.75.

Table 1: Reference ^{10}Be production rates due to spallation, normalized to the 07KNSTD standardization, used in version 2.2.

Scaling scheme	St	De	Du	Li	Lm
Reference ^{10}Be production rate due to spallation (atoms g^{-1} yr^{-1})	4.49 ± 0.39	4.41 ± 0.52	4.43 ± 0.52	4.87 ± 0.48	4.39 ± 0.37

2.3 Revision of muon interaction cross-sections for ^{10}Be production

The cross-sections for ^{10}Be production by muon interactions of Heisinger et al. (2002a,b) were derived from ^{10}Be measurements that were normalized to a standard compatible with the KNSTD standardization. Thus, in version 2.2 these values are revised to be consistent with the 07KNSTD standardization. The new value for $f_C f_D f^*$ (the summary cross-section for ^{10}Be production by negative muon capture in quartz) is 5.0043×10^{-4}. The new value for σ_{190} (the cross-section for ^{10}Be production by fast muons with energy 190 GeV in quartz) is $8.5 \pm 1.2 \times 10^{-29}$ cm^2. These values supersede the values stated in the 'MATLAB function reference' appendix to Balco et al. (2008).

2.4 Users must now specify the standardization used for ^{10}Be and ^{26}Al measurements

The data entry format used in version 2.1 of the online calculators has been modified in that two additional columns must now be entered. These columns indicate the standardization used to measure ^{26}Al and ^{10}Be concentrations. The purpose of this addition is so that users no longer have to renormalize their measurements to a particular standardization before entering them into the calculators. Users can now enter ^{10}Be and ^{26}Al concentrations normalized to any standardization, and the calculator will internally convert the concentrations to be compatible with the 07KNSTD (^{10}Be) or KNSTD (^{26}Al) standardization before proceeding with the exposure age or erosion rate calculations.

As discussed above, specifying the standardization requires knowing both the standard material that was used and the isotope ratio that was assumed for that material. The user specifies this information by entering a particular text code that refers to a standard material/isotope ratio pair. These codes are tabulated in Tables 2 (^{10}Be) and 3 (^{26}Al). **[Note: Tables 2 and 3 have been significantly expanded since this document was originally prepared, and they now appear as a separate document.]** The calculator includes a defined code for all standard/ratio pairs that, to my knowledge, exist in the literature or have ever been used by the majority of AMS laboratories. However, the list may not yet be complete. Users should bring any omissions to my attention.

In addition to the text code for a particular standardization, Tables 2 and 3 show the conversion factor that is used in the calculator to convert measurements made with that standardization to be consistent with the 07KNSTD (^{10}Be) or KNSTD (^{26}Al) standardizations. Note that users should *not* multiply nuclide concentrations by this value before entering them: the conversion is done internally.

References

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