Verifying the Nature of the 5480 BC Cosmic-ray Spike by Measuring ^{10}Be in Ice Cores from Antarctica and Greenland

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ABSTRACT

Ice cores from West Antarctica and Greenland are used to measure cosmic-ray produced Beryllium-10 and verify the cosmic-ray spike around 5480 BC that was found in the Carbon-14 tree-ring record. Since ^{10}Be is removed from the atmosphere much quicker than ^{14}C, it is a better indicator of the timing and magnitude of unusual cosmic-ray spikes, such as the 5480 BC Event. Miyake et al. (2017) speculated this event may be due to an unusually large solar proton event (SPE), a "special state" grand solar minimum or a combination of the two. By measuring the ^{10}Be concentration in ice samples at *annual resolution* from 5500 to 5470 BC, we expect to learn more about the nature of the 5480 BC Event.

BACKGROUND

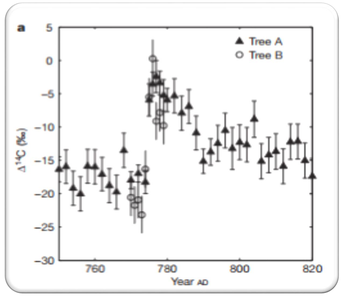

Figure 1: Carbon-14 variations in tree-rings from 775 AD Event (Miyake et al. 2012)

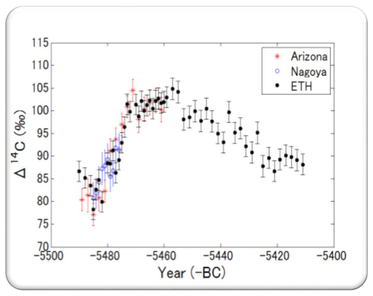

Figure 2: Carbon-14 variations in tree-rings from 5490 BC – 5410 BC (Miyake et al. 2017)

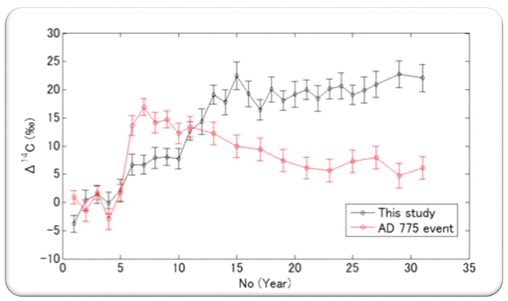

Figure 3: Carbon-14 variations from 5480 BC event compared to 775 AD event. Year zero denotes the start of each event (Miyake et al. 2017)

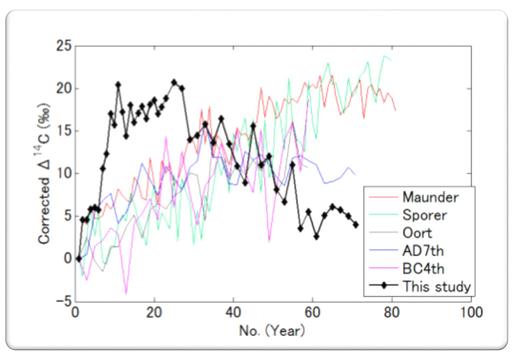

Figure 4: Carbon-14 variations from 5480 BC event compared to grand solar minimums. Year zero denotes the start of each event (Miyake et al. 2017)

MOTIVATION

- Recent study of Miyake et al. (2017) shows rapid increase in ^{14}C around 5480 BC (Fig. 2) – but nature of this event still unclear
- ^{14}C increase at ~5480-5470 BC is ~30% larger than 775 AD event, but takes a factor 10 longer (Fig. 3)
- ^{14}C increase is much more rapid than for typical grand solar minima (like Maunder, Sporer, Oort) (Fig. 4)
- We already have ^{10}Be data in Antarctic ice core at ~20 year resolution; shows a peak at ~5480 BC (Fig 5), but resolution too low to determine the magnitude/duration of the event
- ***Need annual resolution ^{10}Be data in ice core***

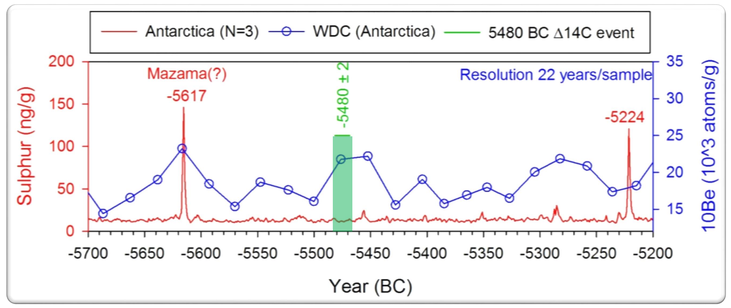

Figure 5: Low resolution ice samples reveal peak in ^{10}Be around 5480 BC. Better resolution is needed to fully understand how rapidly the peak occurs, the magnitude of the peak and the behavior of the ^{10}Be concentration after the peak (Sigel et al. 2015)

SAMPLES AND METHODS

- Ice samples from West Antarctica (WDC06A) and Greenland (GISP2) corresponding to interval of 5500 - 5470 BC are melted; each sample (60-100 g) represents about one year of snow accumulation
- ^{9}Be carrier (0.14 mg) is added to each sample to obtain ^{10}Be/^{9}Be ratios of ~1x10^{-13}. Isolate Be using cation exchange chromatography, convert to BeO, load target.
- ^{10}Be/^{9}Be ratio will be measured by AMS at PRIME Lab (Purdue Univ.). Results used to determine concentration of ^{10}Be

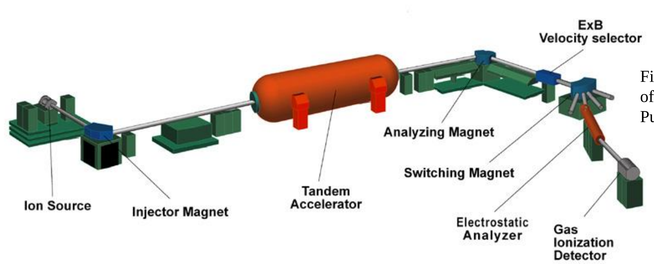

Figure 6: Diagram of AMS facility at Purdue University

DISCUSSION

- Zero solar modulation (no heliomagnetic field) increases ^{14}C or ^{10}Be production by 60-70%. Larger increases most likely require contribution from SPE. ^{14}C data between 5480-5470 BC suggest production rate increase up to ~110 ± 50% - but large uncertainty hinders conclusive interpretation
- Annual ^{10}Be data in ice core (in progress) should be able to determine the increase in ^{10}Be production between 5480-5470 much more precisely (± 10%), and thus provide more insight into the nature of the unusual cosmic-ray spike at ~5480 BC.

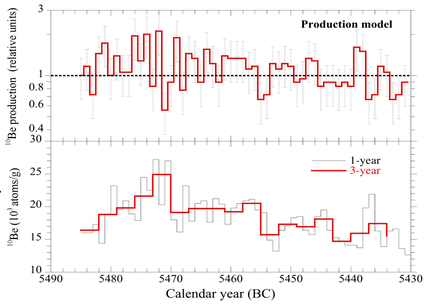

Figure 7: Expected ^{10}Be concentration in ice samples from 5490 to 5430 BC, (bottom graph) based on variations in the relative ^{10}Be production rate (top graph) as derived from ^{14}C data (Miyake et al. 2017).

FUTURE WORK

- Finish chemistry and measurements of ^{10}Be in Antarctic and Greenland ice samples to determine magnitude and timing of the 5480 BC Event
- Use the 5480 BC Event to better date the largest volcanic eruption in Holocene, i.e. the Mazama Volcano (aka Crater Lake, Oregon) at ~5600 BC (Fig. 5)

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