Boron isotope fractionation in combusted plants during wildfires

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Abstract

In light of climate change, wildfires are concurrently becoming more frequent and devastating worldwide. Though we have a good understanding of fire frequency changes in the past using charcoal analysis, records of the characteristics of these fires, such as fire severity, are lacking. This limits our ability to model how fire severity responds to climate change. Boron isotopes in clay minerals show promise as a novel fire severity proxy, where increased $?^{11}B$ is correlated with higher fire severity. Through reacting boron leached from experimentally combusted plants with clays, we determine that the observed correlation with fire severity is likely caused by input of isotopically heavier boron from combusted leaves. In contrast, combusted barks lower the $?^{11}B$ of clays upon reaction. Despite the different results, in both experiments with barks and leaves, similar boron isotope fractionation is observed during boron adsorption onto clays, where the lighter ^{10}B is preferentially adsorbed. Therefore, the different results are likely caused by the different boron isotope composition of leaves and barks, where leaves have a much higher $?^{11}B$ (˜30 bark (˜9 $?^{11}B$ of clays: changes to the $?^{11}B$ of clays were observed only when reacting with bark combusted at >300 °C, or with leaves combusted at >550 °C. This could be because more boron can be leached into solution from materials combusted at higher temperatures, which in turn results in greater adsorption onto clays during reactions. Clays have higher $?^{11}B$ in soils affected by high severity fires that consume tree crowns, because these fires combust more leaves that then deposit their isotopically heavier boron content into the soil. This relationship could help complete our fire record and improve our ability to predict future fire characteristics.

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1. Introduction & Rationale

Wildfires are increasingly a prominent hazard due to climate change. It is difficult to model variations in fire characteristics in order to predict future wildfire behavior, because we lack knowledge of how wildfires behaved in the past. We investigate boron isotopes as a potential novel proxy for past fire severity. In the soil profile, biochemical cycling is the greatest factor that controls the boron budget. It is therefore likely that disturbances to this biological cycling during wildfires could impart boron signals in the soil. Our experiments have shown that boron isotopes in the soil correlate with fire severity (Figure 2; Lu et al 2022), thus boron isotopes could possibly be used as a novel proxy for fire severity in past wildfires. However, it is unclear how this correlation may arise. This study aims to decipher how different fire severities may impart boron isotopic signals in the soil during and after wildfires.

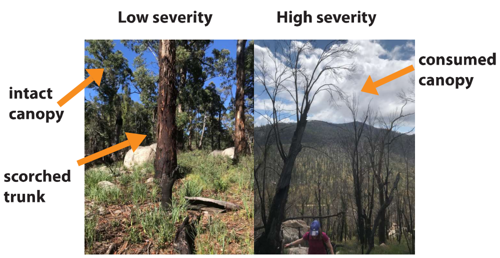

Figure 1. Differences between low and high fire severity. Fire severity is an important metric that measures the impact on the environment. More biomass is consumed in a higher severity wildfire.

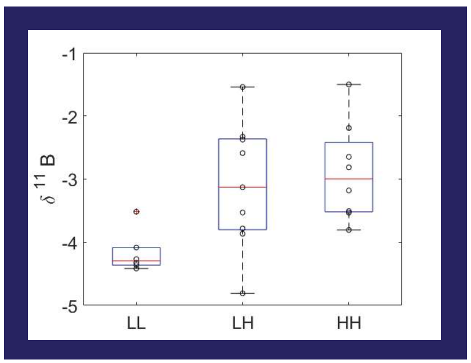

Figure 2. Our previous study shows that soil from sites (in Yengo National Park, NSW, Australia) that experienced at least one high severity fire (H) tend to have heavier boron isotope composition compared to those that only experienced low severity fires (L) (Lu et al. 2022).

2. Experiment set up

In this study, we analyse water-exchangeable boron in bark charcoals collected from wildfire sites. We also react clay with leaching solutions of artificially combusted barks and leaves to test how this interaction may alter the boron isotope compositions of clays.

Combust plant material in furnace → Leach B from combusted plant → React leachate with clay → Analyse B isotopes in clay

3. Results

Boron is an essential micronutrient for plants. Trees strongly fractionate boron isotopes, since the lighter ^{10}B is preferentially incorporated by plant cells. This leads to leaves having heavier boron isotope compositions than barks (Figure 4).

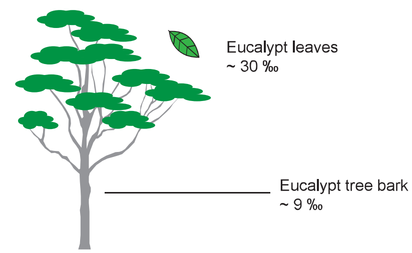

Figure 4. Boron isotope compositions of eucalypt leaves and barks measured in this study

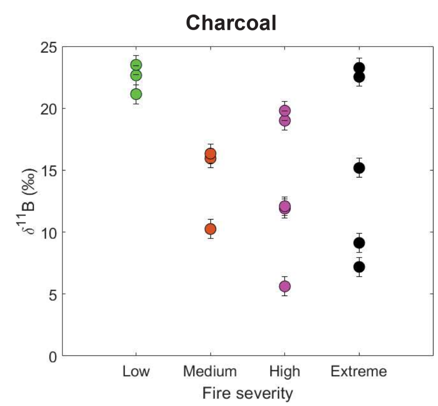

Figure 5. Boron leached with hotwater from natural bark charcoals have lighter isotope composition for samples from sites of higher fire severity

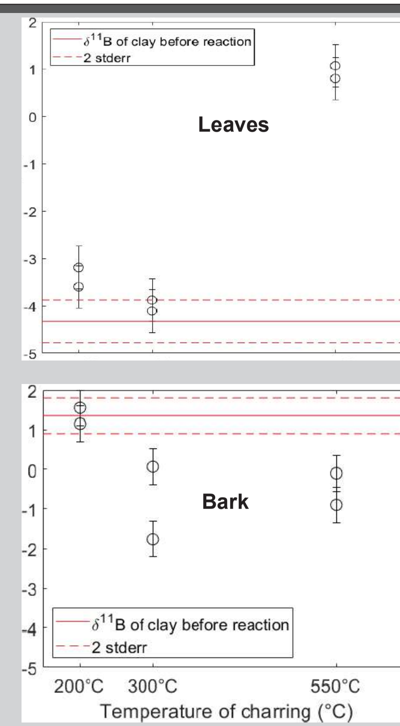

Figure 6. Clays that react with leaves combusted at high temperatures gain heavier boron isotope compositions. Those that react with combusted bark contrastingly gain lighter boron isotope compositions.

4. Conclusions

- Charcoal from higher fire severity sites leach lighter boron isotope compositions into solution (Figure 5).
- At high enough temperature, combusted leaves increases the boron isotope composition of clay, while combusted bark decreases it (Figure 6).
- Input from combusted leaves is the likely cause of heavier boron isotope composition of soils in higher severity wildfires.