USING CHARCOAL FORMED DURING AN ASTEROID COLLISION TO RECOGNIZE SMALL IMPACT CRATERS ON EARTH AND TO LEARN ABOUT ENERGY DISTRIBUTION AROUND SUCH FEATURES

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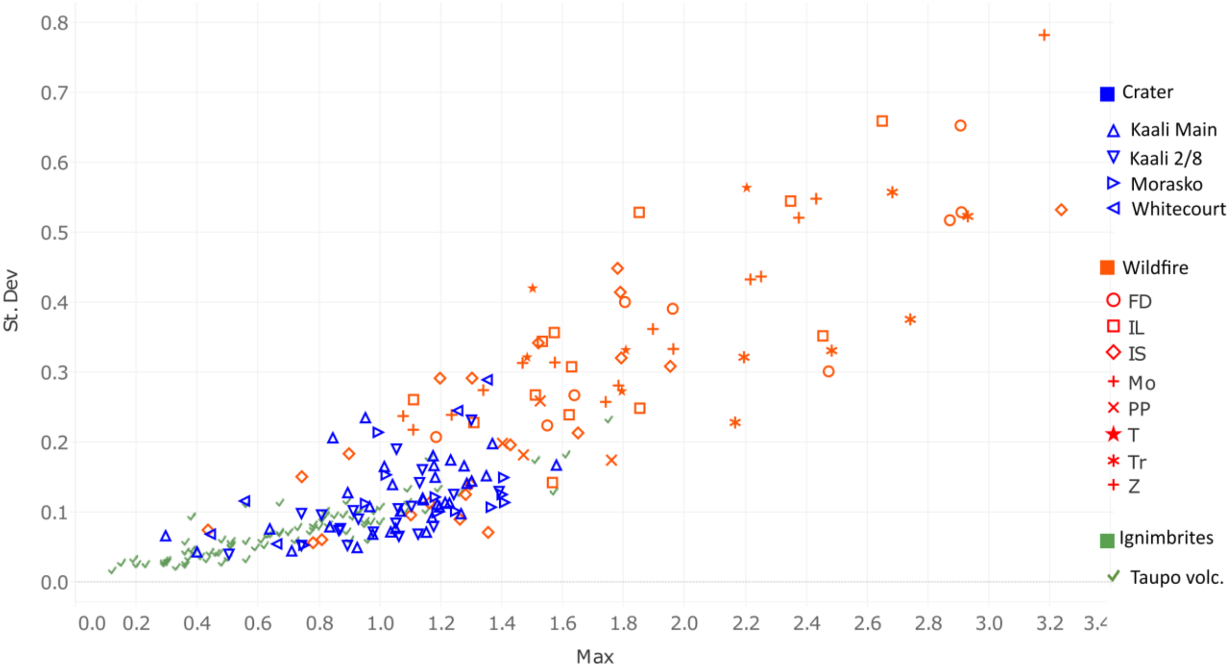

Figure 1. Comparison of reflective properties of charcoals: impact (Kaali Main [100m], Kaali 2&8 [double crater 27m and 36m], Morasko [100m], Whitecourt [36m]), wildfire (IS and IL are in from soil on top of Ilumetsa craters, FD is from recent wildfire in southern UK, T soil samples from Sweden, other ones from different locations in North America) and ignimbrite (data on Taupo volcano in New Zealand by[1]) in terms of their maximal reflectance and standard deviation. The plot shows differences between reflective properties of charcoals formed by those processes.

Introduction: Recognizing small terrestrial impact craters developed in unconsolidated materials is a widely recognized problem [2]. In such cases, impact cratering indicators, established based on larger structures formed in lithified rocks, are not useful: there are no shatter-cones and the amount of shocked quartz produced during the impact is very small and spread out over a large area. Because of that the main (and in most cases the only) recognition criterium applied for the small impact craters in unconsolidated materials is recognition of the preserved meteorite fragments associated spatially with the crater. However, recognizing such meteorites is also problematic due to a limited and highly variable (due to environmental conditions) meteorites survival time, and ease of finding them (especially lack of methods for screening for remains of low-metal, highly weathered impactors).

Problem: As a result, the terrestrial small crater record is incomplete, and tens of structures with diameters ~100-150 m in diameter are waiting to be discovered [3]. This problem that cannot be resolved using currently available tools for recognizing those structures, because they are not applicable to those cases.

Hypothesis: We suggest that we can use unusual properties of charcoals formed during the impact and recently found within proximal ejecta blanket of 4 different confirmed impact structures (Kaali Main, Kaali 2/8, Morasko, Whitecourt) to define a new impact indicator applicable to small impact craters.

Samples and Methods: We have analyzed charcoal found in proximal ejecta blankets of four confirmed Holocene impact craters (Fig. 1): Kaali Main [4], Kaali 2/8, Morasko Main [5,6], and Whitecourt [7,8]. All of those sites are associated with iron meteorites, have diameters from 30 m to 110 m, and were dated to be 5 ka (Morasko), 3.5 ka (Kaali) and 1.1 ka (Whitecourt). We compared those results to wildfire charcoals from different locations in Europe (Estonia, UK, Poland and Sweden) and North America (USA), as well as with charcoal from Taupo ignimbrite in New Zealand [1].

Reflectance (Ro) of charcoal can be used to determine the level of graphitisation of charcoal which relates to the total amount of energy delivered to the sample [9]. In short – the more reflective charcoal is, the more energy (what can be simplified to temperature over time) was required to produce it. We have measured reflectance of wildfire and impact charcoal using a Zeiss Axio-Scope A1 optical microscope, with a TIDAS-MSP 200 microspectrometer under oil.

Results: Charcoals produced by wildfires, within ignimbrites and those from proximal ejecta of impact craters have different reflective properties (Fig. 1). Three parameters that are the most useful to distinguish them are: the average reflectance (wildfires >1.0%, ignimbrites <0.5%, impact charcoals ~0.75%), standard deviation of the sample (wildfires >0.18, ignimbrites <0.1 and impact charcoals ~0.13), and maximal reflectance (wildfires >1.4%, ignimbrites from 0.2% up to 1.8%, and impact charcoals <1.4%).

Discussion: The differences in reflective properties reveal peculiarities of those processes. Wildfires have the highest average and maximal reflectance values (up to >3.5%) because flaming combustion is exothermic process and provides energy to charcoal what increases its reflectivity [10]. Wildfire charcoals have the highest st.dev. within a single sample (and often within a single grain there are noticeably more and less reflective sections) because it is a very heterogenous environment, where significantly burned areas can be found just next to not affected sites and even a single branch can have outsides that totally turned to high-reflective charcoal, while its' core is still a normal wood).

Ignimbrite charcoals are formed due to interaction of plants with hot pyroclastic flows. Wood is turned into charcoal without flaming, and its resulting reflectance is directly correlated with the initial temperature of the rock [11]. Because conditions within any given place of the pyroclastic flow (after it stops) are thermally uniform and wood has plenty of time to equilibrate with its surroundings, the reflectance of each individual sample is very homogenous. The average values are close to maximal values and st.dev. is very low. The variation within individual sample is low, but the variation between samples can be significant. Samples from the same pyroclastic flow, found within the same outcrop only cm from each other can have significantly different reflectances [1]. This reflects small scale discrepancies in initial temperature of the ignimbrite that is related to the amount of cold rocks intermixed into the volcanics, and distance to the edge of the deposit (and the rate of its cooling).

The properties of impact charcoals suggest that they were formed by a process similar, but not the same to the formation of charcoals within ignimbrites. Impact charcoals have a slightly higher av. Ro – their formation probably required higher energies (but lower than those in the wildfires). Lack of higher than 1.5% max Ro shows that pieces of the wood have not undergone combustion [10]. St.dev. is slightly higher than in ignimbrites what shows that the local thermal conditions within ejecta blanket were more heterogenous. This may be explained by the influence of thickness of the heated layer within proximal ejecta – as it would cooled down quicker than the ignimbrites. Alternatively, it may be caused by a less uniform thermal profile within the ejecta composed of small clasts/fragments of sediment heated to significant temperatures and the rest of the material much colder. Despite the fact that reflectance values within a single sample of impact charcoals are more variable than within ignimbrites (what is showed by the lower st.dev. of ignimbrites charcoals), samples from impact charcoals (from different impact craters from different times and continents) are much more similar to each other than samples from the same ignimbrite flow. Ignimbrite samples from a single flow form a nearly linear trend from the ~0.1% av. Ro and 0.02 st.dev. up to 1.4% av. Ro and 0.23 st.dev, while most of the impact charcoals cluster around a single value (0.75% av. Ro and 0.13 st.dev.). This suggests that the process of production of impact charcoal within proximal ejecta blanket differs from this within ignimbrites, and that it is guided by some thresholds.

Conclusion: Impact charcoals can be used to distinguish small terrestrial impact craters developed in unconsolidated material, and to learn more about energy distribution during their formation.

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