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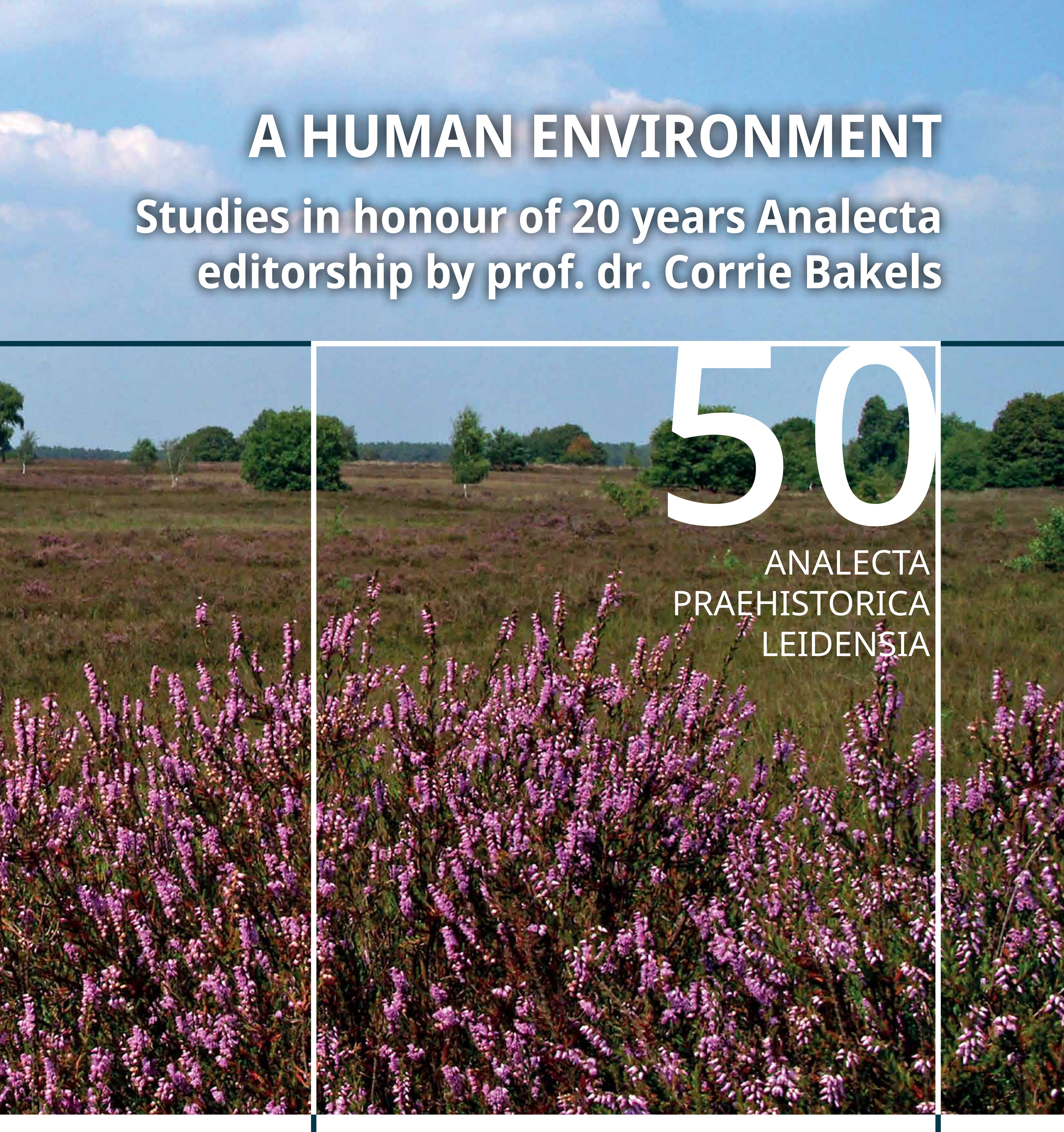

A HUMAN ENVIRONMENT

Studies in honour of 20 years Analecta editorship by prof. dr. Corrie Bakels

50

ANALECTA PRAEHISTORICA LEIDENSIA

edited by
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Neandertal advice for improving your tinder profile: A pilot study using experimental archaeology to test the usefulness of manganese dioxide (MnO_2) in Palaeolithic fire-making

Andrew C. Sorensen

The collection of the black minerals comprised primarily of manganese dioxide (MnO_2) by Neandertals in France is a known archaeological phenomenon, with some of these blocks exhibiting evidence of having been abraded to produce powder. This has generally been interpreted as the production of black pigment that may have been applied to the body as a form of symbolic expression. However, Heyes and colleagues (2016) demonstrate that MnO_2 can reduce the auto-ignition temperature of wood by upwards of 100°C and suggest that this special pyrotechnic property of powdered MnO_2 may have been appreciated by Neandertals. Specifically, they suggest that the addition of MnO_2 to tinder materials may have aided in fire-making. The purpose of the pilot study described here is to test the utility of MnO_2 as a tinder enhancer during actualistic fire-making experiments. The flint-and-pyrite fire-making method was employed to produce sparks that were directed onto fluffed tinder fungus (Fomes fomentarius) with and without added MnO_2 to determine if and the degree to which this material improves the ability of the tinder to capture and propagate sparks into a glowing ember. The results of this pilot study lend support to the hypothesis of Heyes and colleagues by demonstrating that MnO_2 improves the spark capturing efficiency of tinder material over untreated tinder, thereby reducing the time and energy required to produce fire using the percussive fire-making method. However, it was also observed that the incorporation of pyrite (FeS_2) dust into the untreated tinder over the course of the experiments appeared to improve its ability to capture sparks, lending to the idea that pyrite powder added to tinder prior to making fire could also expedite the process and largely negates the need for collecting MnO_2 for this purpose.

Keywords: Fire-making, Neandertals, manganese dioxide, tinder, Palaeolithic, experimental archaeology

1. Introduction

The ability to make fire is an exclusively human trait. Yet, the origins of fire production technology remain largely a mystery. Sporadic evidence for hominin fire use is known from at least 1.5 Mya (Berna *et al.* 2012; Gowlett and Wrangham 2013; Hlubik *et al.* 2017), with this practice appearing in the archaeological record with more frequency after around 400-300 kya with the appearance of Neandertals at the dawn of the Middle Palaeolithic (Roebroeks and Villa 2011a; Shimelmitz *et al.* 2014). It is still unclear, however, if this apparent increase in fire use is due to their

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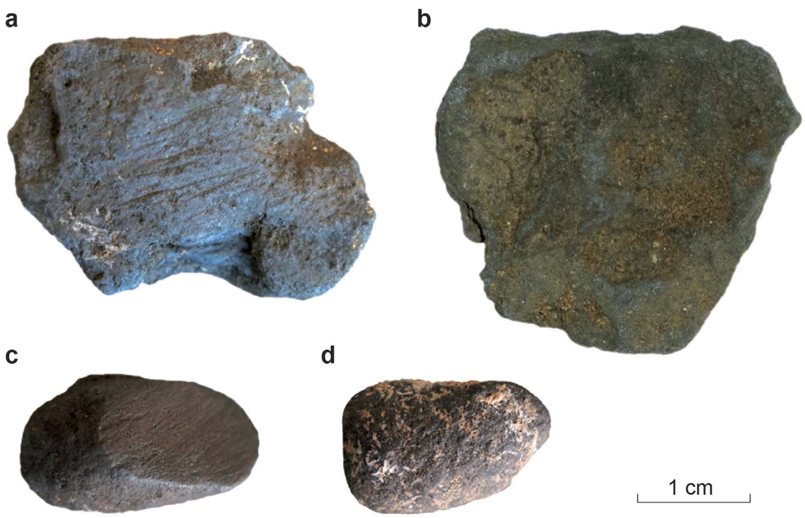

Figure 1: Examples of manganese dioxide (MnO_2) blocks collected from Middle Palaeolithic layers at Pech de l'Azé I (Dordogne, France). Blocks (a) and (c) exhibit evidence of grinding, while blocks (b) and (d) are unmodified. After Heyes *et al.* 2016.

having developed the ability to make fire from scratch. The tools used to perform this task – so-called flint 'strike-a-lights' used to percuss fragments of pyrite to produce sparks – do not appear until much later in the Palaeolithic, first among late Neandertals in France (Sorensen and Rots 2014; Rots 2015; Sorensen *et al.* 2018), and then among Upper Palaeolithic modern humans in Western Europe (Weiner and Floss 2004; Slimak and Plisson 2008; Sorensen *et al.* 2014). This is especially true after the Last Glacial Maximum ca. 20 kya when archaeological instances of fire-making tools, though still rare, begin to appear with more regularity (Stapert and Johansen 1999; Winiarska-Kabacińska 2009; 2010; Pyżewicz 2015; Osipowicz *et al.* 2018).

The idea that Neandertals could make fire remains contentious, with some authors arguing that they very likely possessed this capability (Roebroeks and Villa 2011b; Sorensen 2017), while others suggest fire-making rests solely in the realm of modern humans (Sandgathe *et al.* 2011a; 2011b; Dibble *et al.* 2017; 2018). Claims of direct evidence of fire-making by Neandertals in the form of dozens of Mousterian of Acheulean Tradition (or MTA) bifaces in France possessing microwear related to the production of fire have been put forward recently by Sorensen *et al.* (2018) and lend strong support to the former argument.

Prior to these findings, a novel study by Heyes *et al.* (2016) sought to test the pyrotechnic properties of manganese dioxide (MnO_2), a black mineral found in abundance at some late Neandertal sites in France, often exhibiting traces of having been ground into powder (figure 1). The traditional interpretation of this evidence has been that the powder was likely used as a pigment for body painting (Soressi and d'Errico 2007). Heyes *et al.* challenged this traditional interpretation on the grounds that 1) for use as black pigments, other materials (charcoal, soot) were more readily available for less search costs, and 2) through compositional analyses of the manganese blocks. Concerning this latter point, Heyes *et al.* found that adding powdered MnO_2 to wood turnings lowered the ignition temperature of this material by upwards of 100°C, ultimately suggesting that MnO_2 may have been collected by Neandertals to aid in fire-making by acting as a tinder enhancer. It remains difficult to prove definitively that Neandertals were using MnO_2 for this purpose, however, and further investigation is warranted.

One aspect of the Heyes *et al.* study that remains to be explored is the applicability of MnO_2 as a tinder enhancer under actualistic fire-making conditions. In their study, the experiments were performed under lab conditions using machined wood turnings as the tinder material, which could be considered much too coarse for use in more traditional fire-starting methods, and matches to ignite the tinder material. To add validity to their hypothesis, the utility of MnO_2 as a tinder enhancer should be tested using a fire-production method known to Palaeolithic peoples, specifically the stone-on-stone method (Sorensen *et al.* 2014; 2018), which can be described as follows. A piece of flint (commonly referred to as a 'strike-a-light') is brought together forcefully with a fragment of the mineral pyrite (FeS_2) to produce sparks. These sparks are directed onto and eventually 'captured' by a bed of generally fibrous or fluffy tinder material, producing a glowing ember that can ultimately be blown into a flame and used to start a fire. For the small pilot study presented here, a series of six fire-making experiments using hoof fungus (*Fomes fomenatarius*) as tinder were performed in order to determine if, and to what extent, the addition of MnO_2 to a tinder material improves its ability to capture sparks, thus expediting the fire-making process.

2. Materials and Methods

Fire-making experiments were performed indoors at the Leiden University Faculty of Archaeology Laboratory for Artefact Studies using a Grand-Pressigny flint crested blade strike-a-light and a halved pyrite nodule collected from the beach near Cap Gris-Nez (France), where the tip of the strike-a-light was rubbed forcefully against the broken surface of the pyrite to produce sparks (figure 2). Both elements of fire-making set were used throughout the experiments in an effort to control for possible spark production variability between different strike-a-light/pyrite combinations. Moreover, both elements had been used previously by the author to make fire, with the surface of the pyrite nodule fragment homogenously flattened and the end of the strike-a-light already rounded from use. This was done to ensure that the morphologies of these contact surfaces would be largely similar for all experiments (as opposed to, for example, using a freshly made strike-a-light tool whose end would start sharp and become increasingly dull over the course of the experiments, likely creating variability in spark production).

The sparks produced by the flint and pyrite were directed onto a bed of tinder made of finely shredded *Fomes fomentarius* (collected by the author in Skåne Province, Sweden). Colloquially known as tinder fungus or hoof fungus, *Fomes fomentarius* is a well-known tinder material that has been used by Stone Age (Stapert and Johansen 1999; Pétrequin 2015; Wierer *et al.* 2018) and modern peoples alike in temperate and boreal zones across the Northern Hemisphere (see Roussel 2005, and sources therein). The tinder was processed into a fluffy mass for the experiments by scraping the well-dried velvety *amadou* portion of the fruiting body with a flint flake (figure 3). For each of the experiments, 0.3 g of tinder was used either 'as is' (control) or thoroughly mixed with 0.1 g commercial manganese dioxide (MnO_2; specifically, pyrolusite) powder acquired from Sigma-Aldrich (product reference 310700). The tinder for each experiment was placed inside a 4.5 cm diameter and 2.2 cm deep ceramic bowl to control for the surface area exposed to the sparks (figure 2). The tinder was tamped down into the bowl to form a continuous and more or less uniformly thick bed (3-5 mm) to increase connectivity between the tinder fibres and ensure consistency between experiments.

The experimental program was divided into three series (A-C) of two experiments, with one experiment using tinder treated with MnO_2 and another using

Figure 2: Materials and gesture used for fire-making experiments. The flint crested blade (right hand) was pressed firmly against the flat broken face of the halved pyrite nodule (left hand) and then forcefully pulled upwards to produce showers of sparks that fell into the small ceramic bowl containing the tinder.

Figure 3: Photos of hoof fungus (*Fomes fomentarius*) used as tinder in the fire-making experiments, both in its natural state still adhering to a tree (a) and during processing (b), where the velvety, upper portion of the fruiting body interior (the *amadou*) was scraped into a fluffy mass using a flint flake.

untreated tinder, for a total of six experiments (1-6). Each experiment was comprised of 20 sets of five strokes (of the flint against the pyrite) that produced sparks (100 total), with the number of strokes per set in which sparks were captured recorded. The total number of strokes needed to achieve five spark-producing strokes per set was also recorded. These data were analysed and plotted using Microsoft Excel.

3. Results

A total of six fire-making experiments were performed for this small pilot study: Experiments 1, 3 and 5 used *F. fomentarius* tinder treated with MnO_2, and Experiments 2, 4 and 6 used untreated tinder (table 1). On average, it took 144.7 strokes of the flint strike-a-light against the pyrite to produce sparks 100 times (range: 131-158 total strokes).

Of these 100 spark-producing strokes for each experimental series, Experiments 1, 3 and 5 using tinder treated with MnO_2 achieved 40, 34 and 27 spark captures, respectively (average: 33.7). For Experiments 2, 4 and 6 using untreated tinder, 19, 6 and 17 sparks were captured, respectively (average: 14). Overall, this suggests a 140.7% increase in the rate of spark capture for tinder treated with MnO_2 over untreated tinder.

Each experiment was broken into 20 sets of five spark-producing strokes. Of these 20 sets, experiments using tinder treated with MnO_2 (1, 3 and 5) were able to capture at least one spark in 100%, 90% and 95% of the sets, respectively, while experiments using untreated tinder captured at least one spark in only 60%, 25% and 55% of the sets, respectively.

Figure 4 plots the number of sparks captured per set of five spark-producing strokes over 20 sets in order to determine if there were any changes in tinder effectiveness over time. The trendlines show that the tinder treated with MnO_2 had higher and relatively consistent spark-capturing capacities over the course of the fire-making experiments (*i.e.*, between 1.3 and 2.4 sparks captured per set) compared to experiments using untreated tinder. These, on the other hand, exhibit trendlines suggesting an increase in spark-capturing efficacy over the course of the experiments, with no sparks being captured early on followed by increasing numbers of sparks being captured in later sets approaching the spark-capture rates of the MnO_2-treated tinder (*i.e.*, between 0.7 to 2.2 sparks captured per set near the ends of the experiments).

Another way to visualize this improvement in untreated tinder over time is seen in figure 5. Here, the sets of five spark-producing strokes are combined into four groups of five sets (*i.e.*, Group 1 = Sets 1-5, Group 2 = Sets 6-10, etc.), with the bars presenting the percentage of individual sets per group having captured at least one spark. Again, we see that the ability of the MnO_2-treated tinder to capture sparks remains high throughout the experiments (80-100% of sets capturing sparks per grouping), while the untreated tinder captured no sparks in any of the experiments during the first five sets, but captured progressively more sparks during subsequent sets, ul-

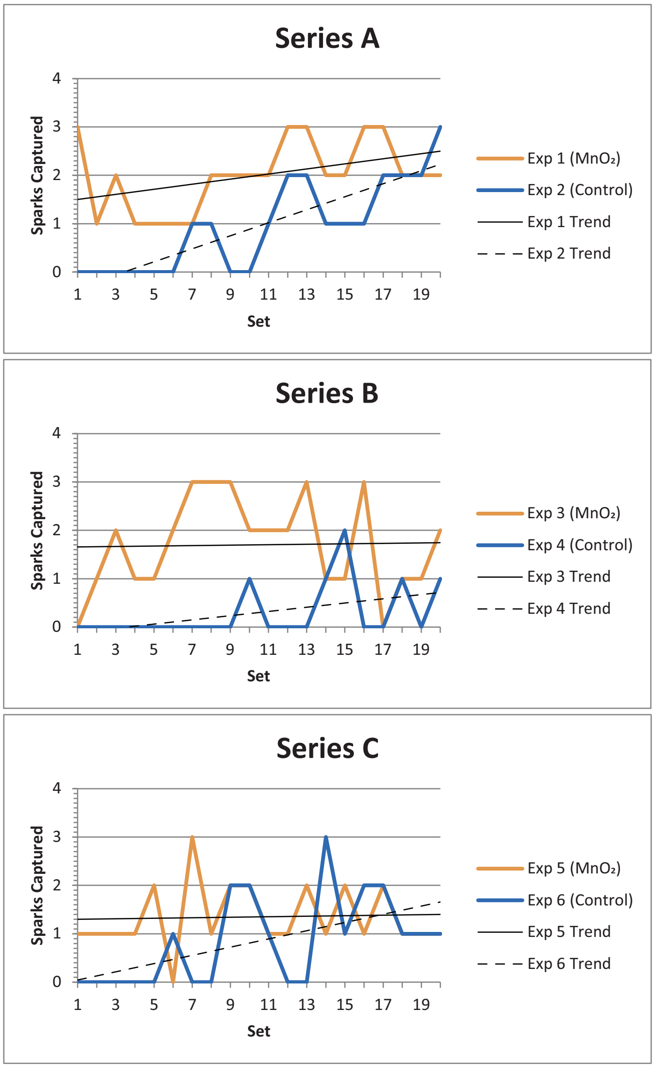

Figure 4: Line graphs plotting the number of sparks captured per set of five spark-producing strokes during fire-making experiments using tinder mixed with manganese dioxide (MnO_2) and untreated tinder (Control).

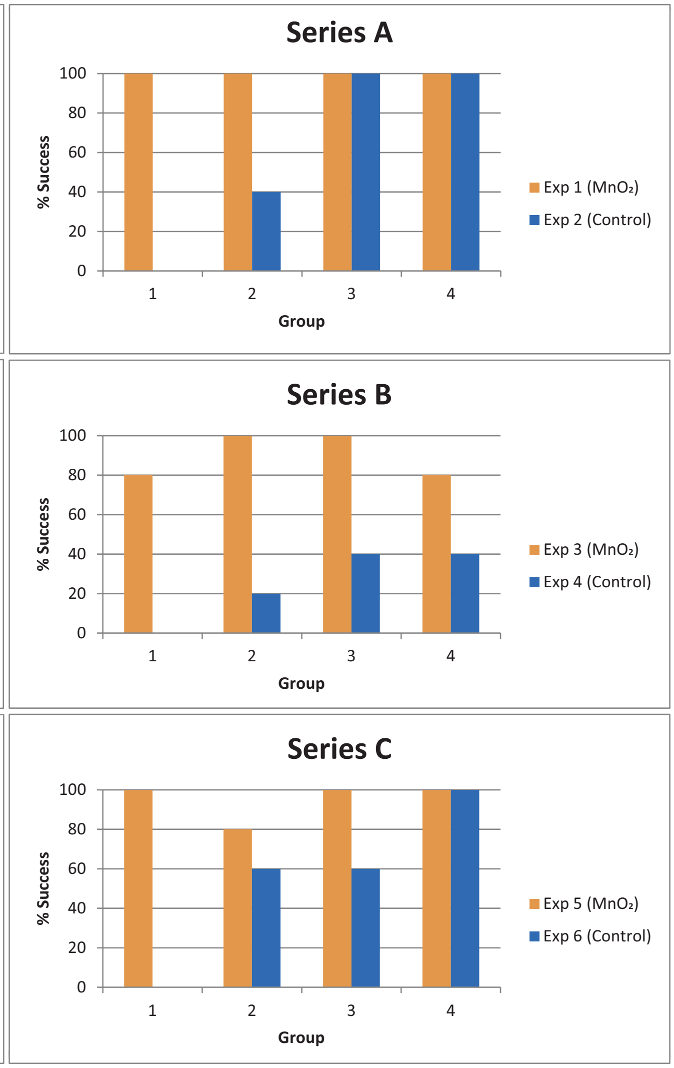

Figure 5: Bar graphs indicating the rate of spark capturing success over the course of the fire-making experiments using tinder mixed with manganese dioxide (MnO_2) and untreated tinder (Control). Each group is comprised of five sets of five spark-producing strokes, with the rate of success measured as the percentage of sets within a group where at least one spark was captured.

timately reaching a 100% success rate in line with the MnO_2-treated tinder in two of the three experimental sets (Series A and C in figure 5).

4. Discussion

Fire was very likely an important aspect of the day-to-day lives of Neandertals, as it is among all hunter-gatherer societies of today, and any means to improve the success rate of fire-starting events would have been viewed favourably by these peoples. Possessing the ability to produce fire when and where it was needed would have been extremely advantageous, allowing Neandertals to cook their food (Henry *et al.* 2011; Barkai *et al.* 2017), to produce tools (Wragg Sykes 2015; Kozowyk *et al.* 2017; Aranguren *et al.* 2018) and to very effectively control their environment (see Clark and Harris 1985 for an overview of the many advantages fire affords). This includes both the means to regulate their microclimate by warming up their bodies and living spaces, but also to shape the landscape to their benefit, perhaps using fire to clear areas to make way

Material	Series	Exp. #	$\underline{M}nO_2$/ $\underline{C}$ontrol	Set	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Totals
				Group	**1**					**2**					**3**					**4**					
Fomes fomentarius (F)	A	1	M	Strokes	9	8	8	6	5	5	7	8	5	11	7	9	8	7	8	7	6	8	11	10	153
				Sparks	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	100
				Captures	3	1	2	1	1	1	1	2	2	2	2	3	3	2	2	3	3	2	2	2	40
				% Success	100					100					100					100					100
Fomes fomentarius (F)	A	2	C	Strokes	10	6	8	9	7	8	13	10	11	10	10	6	5	5	6	6	6	6	6	10	158
				Sparks	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	100
				Captures	0	0	0	0	0	0	1	1	0	0	1	2	2	1	1	1	2	2	2	3	19
				% Success	0					40					100					100					60
Fomes fomentarius (F)	B	3	M	Strokes	12	11	5	7	6	8	6	5	7	5	5	6	8	9	5	7	8	5	8	6	139
				Sparks	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	100
				Captures	0	1	2	1	1	2	3	3	3	2	2	2	3	1	1	3	0	1	1	2	34
				% Success	80					100					100					80					90
Fomes fomentarius (F)	B	4	C	Strokes	7	5	6	8	5	5	6	10	6	6	7	7	8	6	6	6	7	6	6	8	131
				Sparks	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	100
				Captures	0	0	0	0	0	0	0	0	0	1	0	0	0	1	2	0	0	1	0	1	6
				% Success	0					20					40					40					25
Fomes fomentarius (F)	C	5	M	Strokes	8	8	7	7	9	5	9	10	9	10	5	7	8	7	7	7	5	6	7	8	149
				Sparks	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	100
				Captures	1	1	1	1	2	0	3	1	2	2	1	1	2	1	2	1	2	1	1	1	27
				% Success	100					80					100					100					95
Fomes fomentarius (F)	C	6	C	Strokes	6	7	6	8	8	9	6	6	6	6	6	8	6	8	7	6	7	7	9	6	138
				Sparks	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	100
				Captures	0	0	0	0	0	1	0	0	2	2	1	0	0	3	1	2	2	1	1	1	17
				% Success	0					60					60					100					55

Table 1: List of experiments performed and the resultant number of strokes, spark-producing strokes and sparks captured per set (see figure 4) and in total. The grey bars delineate the percentage of sets wherein at least one spark was captured in both groups of five sets (see figure 5) and in total for each experimental series.

for preferred plant species or to attract hunted prey species (see Scherjon *et al.* 2015 for an overview).

The three elements necessary for producing fire using the stone-on-stone method are a piece of flint (or another siliceous raw material), pyrite and tinder. If one of these is lacking, including suitable tinder, then fire-production is extremely difficult, if not impossible. The fine nature of the individual fibres comprising typical tinder materials and the high connectivity between these fibres allows for the easier capture and propagation of sparks produced during fire making. The short-lived nature and relatively low temperature of the sparks produced by pyrite (760-870°C, compared to >1200°C for sparks produced using flint and high-carbon steel; Bois 2004) often prove to be inadequate for igniting more coarse fibered, subpar tinder materials. The addition of MnO_2 to a tinder material appears to aid in the capture and propagation of a spark through a few different mechanisms. Heyes *et al.* (2016) has shown not only that the ignition temperature of a tinder material mixed with MnO_2 is lowered by around 100°C, but also that oxygen atoms released during the combustion of MnO_2 helped to feed the reaction. Moreover, based on observations from the current study, it appears that the powder, by filling in gaps within the tinder, increases the connectivity between the individual tinder fibres, thereby allowing an ember to more effectively propagate. This latter idea is potentially supported by the control experiment trends visible in figures 4 and 5 that appear to indicate the addition of pyrite powder during the fire-making process similarly improves the effectiveness of the untreated tinder over time. These findings suggest that, in lieu of MnO_2, pyrite powder could also be ground into tinder prior to making fire to increase the chances of successfully capturing a spark from the onset.

Nevertheless, the incorporation of MnO_2 into the Neandertal fire-making kit may have been a novel approach to improving the effectiveness of subpar tinders in environments where more suitable tinders were unavailable, or to expedite the fire-making process during the glacial climatic conditions of Marine Isotope Stage (MIS) 4 when the occurrence of MnO_2 in Middle Palaeolithic archaeological layers becomes more regular (Demars 1992; Heyes *et al.* 2016). Whether this was the primary purpose for collecting MnO_2 or simply a secondary use of a material already on hand for other reasons is difficult to say. However, the small amount of MnO_2 needed to improve tinder is in contrast to the high abundance of MnO_2 present in some Middle Palaeolithic archaeological layers, suggesting this material likely had multiple uses. Nevertheless, the co-occurrence of abraded MnO_2 blocks (figure 1), fireplaces and a probable fire-making tool in Layer 4 at the French Middle Palaeolithic site of Pech de l'Azé I (Soressi *et al.* 2008; Sorensen *et al.* 2018) lends strongly to the idea that fire-making was among these uses.

5. Conclusion

There are two primary findings of this small experimental study. First, the addition of MnO_2 to the *F. fomentarius* increased the effectiveness of this tinder material by 140.7% over the untreated control groups, overall, and importantly, allowed the tinder to more readily capture sparks at the onset of each series of fire-making experiments. Second, it was observed that despite the initial poor performance of the untreated control tinders, the spark capturing efficiency of these tinders increased over the course of the experiments, suggesting the gradual incorporation into the tinder of pyrite dust produced while attempting to make fire also enhanced the overall quality of the tinder. These findings largely support the conclusions of Heyes *et al.* (2016) by demonstrating the utility of adding MnO_2 to tinder to improve its ability to capture sparks from the onset of a fire-making episode, thus decreasing the time and effort needed to make a fire. However, the improved performance of the untreated tinder over the course of the experiments suggests that the addition of pyrite powder prior to making fire would also improve the initial performance of the tinder, making the acquisition and use of MnO_2 specifically for this task largely superfluous. More experiments are currently underway to determine whether or not these trends of improved fire-making efficiency hold for other natural tinders of variable quality.

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