

## Reply to Sandgathe et al.: Neandertal use of fire

Sandgathe et al. (1) agree that fire was not a requisite technology for hominin expansion into northern latitudes, but they suggest that habitual use of fire appeared later than stated in our paper (2), only near the end of the Late Pleistocene. They stress that, despite the growing number of Neandertal sites with solid evidence for fire use, there is also a large number of sites without such evidence (1). Based primarily on their extrapolation of data from two recently excavated Middle Paleolithic sites in the Dordogne (France), they argue that the sequences from many Neandertal sites associated with cold environments do not have evidence for fire throughout them (1). They assume that this challenges whether Neandertals were obligate fire users and proficient at making fire.

Indeed, not all Middle Paleolithic sites contain good evidence for use of fire, but this information also applies to Upper Paleolithic sites and open air as well as rock shelter sites. For instance, of 89 Aurignacian sites in Southern France and Northern Spain (3), only 10 have preserved fireplaces. Many more contain fire proxies such as heated flints, burnt bones or charcoal, and ashes dispersed in the sediments. These findings are exactly the (often underreported) indicators of fire use that we have systematically studied at Middle Paleolithic sites. Again, Upper Paleolithic sites with well-preserved stratified sequences do not always have evidence of fire in all layers, which Sandgathe et al. (1) rightly point out for the Middle Paleolithic. For example, at the Abri Pataud (Dordogne), 2 of 14 main levels, levels 2 and 13, do not have fireplaces. Charcoal particles and some burnt bones were found in level 2 but not in level 13 (4). As for the production of fire, fire-making tools are virtually absent in the Upper Paleolithic record (5). However, nobody would argue that Upper Paleolithic hunter-gatherers were not habitual users of fire.

In fact, the situation is very much comparable for the two time periods, the Middle and Upper Paleolithic. As shown in our paper, Neandertals used fire in a wide range of settings, in interglacial as well as full glacial [including Marine Isotope Stage (MIS) 4 and 3] conditions, and in caves, open air, and rock shelter sites over 250,000 y for a variety of purposes (2). These purposes included the preparation of food and the use of fire as a tool to produce new materials (e.g., glue). These last finds are chronologically scattered over more than 100,000 y at three different sites in two different countries [Inden-Aldorf (MIS 5<sup>c</sup>) and Königsau (MIS 5) in Germany and Campitello Quarry (MIS 7) in Italy]. They make it difficult to envisage that Neandertals developed a hafting technology based on complicated ways of producing pitches using fire as a tool without the knowledge to produce fire itself. The evidence of cooking a variety of local plant foods from two sites almost at the opposite extremes of the Neandertal latitudinal range, Spy (Belgium) and Shanidar (Iraq) (6), again suggests a common and widespread dietary adaptation based on their habitual use of fire.

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