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# Evidence for cosmic airburst in the Western Alps archived in Late Glacial paleosols

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ABSTRACT

Previous evidence for fragments of a cosmic airburst in the Western Alps has been shown to reside in weathering rinds in surface clasts of Late Glacial (LG) (mid-LG-post Allerød) deposits and in Ah horizons of several associated paleosols. In contrast to outlying strata, Younger Dryas (YD) paleosol horizons contain minor reworked airburst evidence that includes melted quartz/pyroxene grains, carbon spherules, glass-like carbon, and with minor differences in microbial populations. New data from LG paleosol profiles show REEs elevated above crustal abundance in several profiles of mid-Late Glacial age, along with elevated Pt concentrations, similar to those found at the YD Boundary in the Greenland Ice Sheet. Pt/Pd ratios that are elevated above background suggest an exogenic influx of Pt from meteoritic ablation and/or airbursts. An increasing number of localities with sedimentary time lines coeval with an airburst (12.8 ka) indicate the event was intercontinental, producing widespread conflagrations archived in local sediment sequences. This is the first instance worldwide in which evidence of the black mat event has been found both in weathering rinds and in paleosols in the Alps, with such information being applicable to reconnaissance beyond Earth such as in the case of Mars.



## 1. Introduction

Originating on the slopes of Mt. Viso in the Western Alps of France, the Guil Glacier, a major tributary to the Durance Glacier, underwent insolation-forced recession starting ~15 ka, leaving only isolated ground moraine in the lower catchment. Stillstand-event moraines at 2400 m asl attest to a slow-down of glacial recession sometime during the Bôlling-Allerød retreat phase, followed by a cosmic airburst (Mahaney and Keiser, 2013; Mahaney et al., 2013a, 2016a, 2016b), coeval with the widespread YDB (Younger Dryas Boundary) event of 12.8 ka. The airburst often produced a dark layer sometimes called the "black mat", which in the Alps is represented

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by carbon encrusted grains in rinds and in paleosols. As elsewhere, the affected sediment typically contains high-temperature carbon (charcoal, soot, carbon spherules, glass-like carbon, melted, welded and quenched grains) and is common across Europe and western North America, but less common across eastern North America. In the Alps, this event was followed by rapid change from a negative to positive glacier mass balance, the advance of Younger Dryas ice, and ensuing moraine construction.

The Guil River catchment (Fig. 1) is aligned along a linear fault channeling the headwaters of the Guil River, to the Durance River and eventually into the Mediterranean Sea. Runoff originates on the western slopes of Mt. Viso (3841 m a.s.l.) on the water divide between France and Italy. Evidence for a cosmic airburst that generated the YDB lays ensconced in local weathering rinds bearing melted grains and glassy carbon spherules previously documented by Mahaney and Keiser (2013) and Mahaney et al. (2016b).

The upper catchment is floored with bedrock, moraine, alluvium, talus, protalus, rockfall, solifluction terraces, and a succession of debris flows (Mahaney, 2008). Whereas recessional moraines are non-existent below 2400 m a.s.l. in the lower valley, the effects of glacial activity and recent erosion are evident on the west-facing valley slopes. At and above ~2400 m a.s.l., the recessional moraines indicate rapid retreat of Late Glacial (Würm–Weichselian) Guil ice from the Durance catchment where it had joined the Durance Glacier (terminus near Sisteron (44° 20′N, 5° 93′E). This is not to say that stillstands of Late Glacial (mid-LG) ice did not occur below ~2400 m a.s.l., but only that if recessionals were emplaced they were short-lived and destroyed, and/or obscured by fluvial erosion as the ice melted and receded. Some carbon in successional stage vegetation, originally present in the Late Glacial soil/parent materials (Ah/C/Cu and C/Cu profiles resident prior to airburst) (Mahaney and Keiser, 2013; Mahaney et al., 2013a), is probably preserved in the paleosols described below. As the Allerød climate episode progressed, the early successional stage alpine grassland of the time (mid-Late Glacial) was probably wet tundra (Mahaney and Keiser, 2013; Mahaney et al., 2013a, 2016a). When the high-temperature cosmic airburst (YDB) descended upon the study area, previously hypothesized by Mahaney et al. (2016a), most life was likely destroyed, with carbon either volatilized, charred, or left as carbon spherules in resident soils (now paleosols), and as opaque carbon in weathering rinds. Some microbes, given various ecological niches in which they thrive, may have survived this event, to finally reside either in weathering rinds or soils later transformed with changes from cold to warmer climates into paleosols. It is conceivable that these 'ancient' bacteria may have left their mark on the present-day metagenome record. The various local lithologies were melted, reformed, and welded into multifarious forms as described below. However, since no impact crater has been identified, it is likely the theorized cosmic event was caused by an airburst fragment emanating from Earth's encounter with the Encke Comet (12.8 ka) (Napier, 2010) thereafter exploding over the Mt. Viso area. The Earth/comet impact is thought to have centered over southern Manitoba, remnants of the impact encountering Earth as the Taurid meteors, which in the early stage-12.8 ka to ~11 ka, were possibly of sufficient mass to maintain positive glacial mass balances in various alpine localities in North and South America and in the Alps, thus sufficient to sustain the YD glacial resurgence linked to the main cosmic event.

Nested recessional mid-LG stillstand moraines at ~2400 m a.s.l., located approximately 1 km from the drainage divide at ~3000 m a.s.l. (Col de la Traversette, Fig. 1), were overrun by a readvance, presumed to be of YD age (sites G1 and G2, Fig. 1) (Mahaney et al., 2016a). Because weathering histories, and hence, paleosols in clastic debris of these mid-LG and YD deposits are similar in depth and other properties, they are considered to have ages separated by centuries or possibly up to a millennium, at best. Whether mid-LG ice

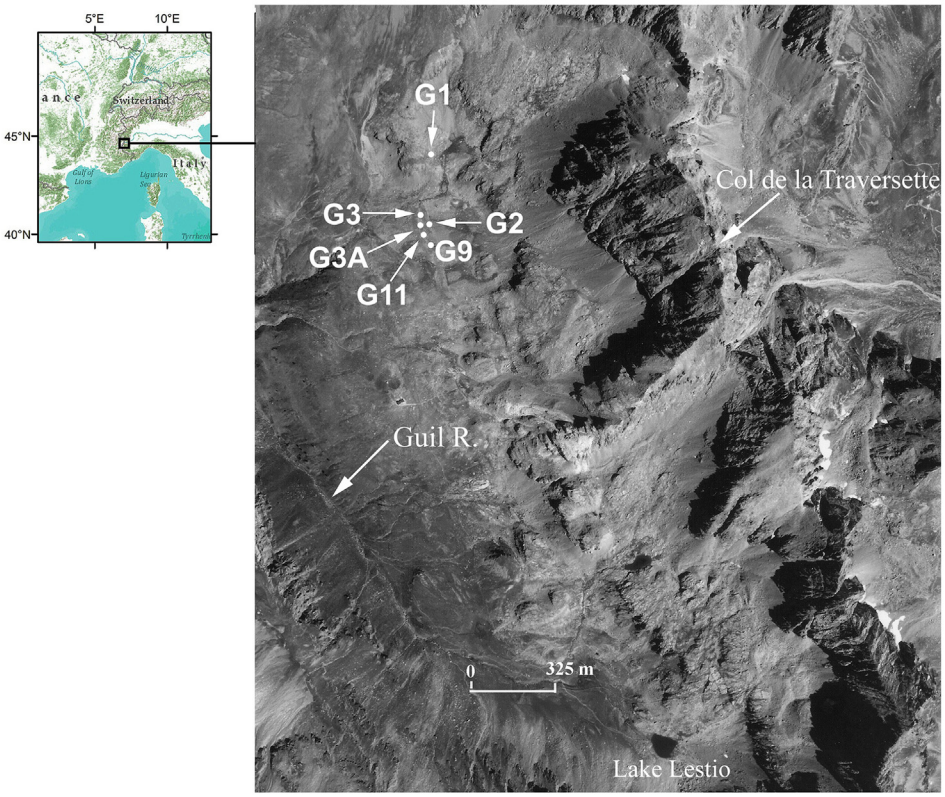


**Fig. 1.** Location of sites in the upper Guil catchment, Western Alps of France.

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