AN AIR-FALL ASH LAYER PROBABLY PRODUCED BY THE LAACHER SEE SUPER-VOLCANO EXPLOSION 13,000 YEARS AGO PRESERVED IN A CAVE DEPOSIT IN THE GROTTA DEI BAFFONI CAVE, FRASASSI GORGE (MARCHE APENNINES, ITALY) – RELEVANCE TO THE YOUNGER DRYAS DEBATE. Alessandro Montanari[1] and Christian Koeberl[2], [1]Osservatorio Geologico di Coldigioco, Cda. Coldigioco 4, 62021 Apiro, Italy (sandro.coldigioco@gmail.com), [2]Department of Lithospheric Research, University of Vienna, Althanstrasse 14, A-1090 Vienna, Austria (christian.koeberl@univie.ac.at).

Introduction: During an interdisciplinary study of the upper Pleistocene-Holocene sedimentary succession in the shallow Grotta dei Baffoni Cave, in the Frasassi Gorge (Marche region of central Italy), Montanari et al. [1] dug a small pit and drilled a ca. 80-cm-dip auger core (PIT-2/H-2) at the far northern end of the cave, some 40 m from the wide cave entrance (Fig, 1A). A ca. 10-cm-thick speleothemic crust (Fig. 1B) was sealing a stratified deposit of silty lime containing terrestrial gastropod shells, small animal bones (lizards, bats, rodents), and limestone clasts. Layer 2 immediately underlying the speleothemic crust contained also charcoal particles, which have been ^{14}C AMS dated at 12965-12721 cal. BP (2σ), i.e., 12,843 ± 122 yr BP. This deposit has been interpreted by Montanari et al. [1] as cave soil that was washed out by the runoff from the atrial area of the cave, eventually settling down into a now-dry water pool. The charcoal was interpreted as deriving from fires lit by early occupants in the atrial area of the cave, suggesting that the cavern was frequented by hunter-gatherer people during the Younger Dryas cold period.

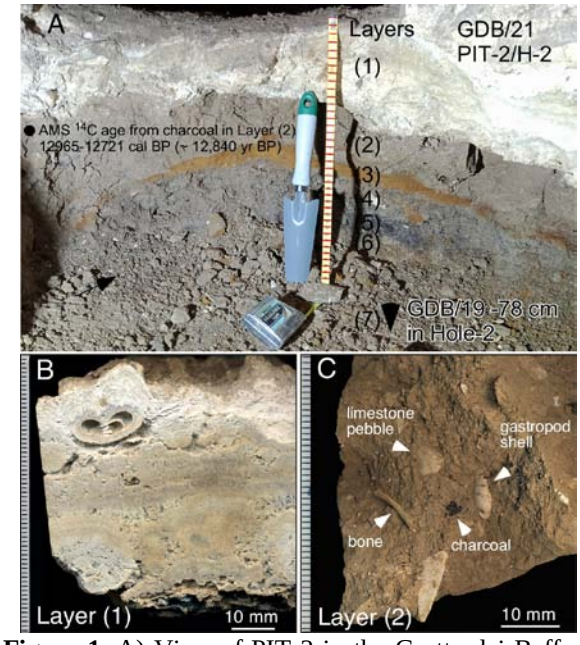

Figure 1. A) View of PIT-2 in the Grotta dei Baffoni Cave as sampled in the fall of 2021; B) Cut section of speleothemic crust of Layer 1; C) Close-up photograph of Layer 2.

Originally, Montanari and coworkers noticed a bright orange-colored, ca. 1-cm-thick horizon at the base of the charcoal-bearing Layer 2, but thought that it represented a banal oxidation band. After resampling the 6 layers exposed in PIT-2, we found out that the thin orange Layer 3 was essentially tephra. Actually, the fine sand-size fraction making up 16 wt.% of the bulk sediment is entirely made up of volcanic glass shards and lapilli (Fig. 2). This discovery led us to the hypothesis that Layer 3 represented an air fall volcanic ash produced by the explosion of the Laacher See super-volcano in central Germany ca. 13,000 years ago (e.g., Reinig et al. [2]).

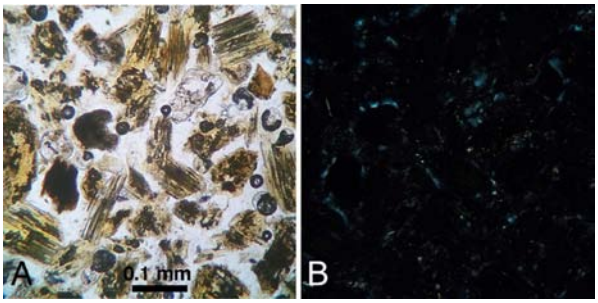

Figure 2. Transmitted light, thin section microphotograph of the >63 μm tephra of Layer 3: A) plain light; B) polarized light.

Sample/Methods: The 6 layers in Fig. 1A were sampled using a trowel on September 26, 2021, and collected in labeled zip-lock bags. Sample 7 was already available from Core H-2 auger-drilled in 2019 by Montanari et al. [1]. About 100 g of each dry sample was wet-washed using a 63 μm polyester filter, and the dry residues were sieved with a stack of standard sieves to determine the grain size distribution. Calcium carbonate content was determined using a Dietrich-Früling water calcimeter (precision ± 2 wt.%) and calibrated with a Carrara marble standard. Total organic carbon content (C_{org}) was determined by the loss on ignition method (LOI).

Results: The results from our preliminary sedimentological analysis of the 7 samples from the Grotta dei Baffoni Cave, PIT-2/H-2, are shown in Table 1.

Table 1. Textural and compositional analysis of the 7 samples of cave sediment from PIT-2 in the Grotta dei Baffoni Cave.

21-09-2021 Sample n. and Site	GDB PIT-2/H2 depth (cm)	CaCO3 (wt. %)	Corg (wt. %) LOI	< 63 μm (wt. %)	63-2000 μm (wt. %)	> 2000 μm (wt. %)
(1) GDB/21 PIT-2	5 ± 5	~ 100	~ 0	//	//	//
(2) GDB/21 PIT-2	14 ± 4	36.839	5.84	80.8	14.6	4.6
(3) GDB/21 PIT-2	20 ± 2	12.943	19.84	83.8	16.0	0.2
(4) GDB/21 PIT-2	23 ± 2	22.803	5.98	93.3	5.0	1.7
(5) GDB/21 PIT-2	27 ± 2	38.956	4.46	74.2	12.8	13.0
(6) GDB/21 PIT-2	32 ± 2	40.812	3.81	70.8	15.0	14.2
(7) GDB/19 Hole H-2	78 ± 8	42.276	2.87	52.1	18.1	29.8

Sample 3, highlighted in orange in Table 1, is texturally and compositionally different from all the other cave sediment layers. The calcium carbonate content is ca. 13 wt.%, compared to ca. 23-42 wt.% in the other samples. The sample practically lacks a coarse grained size fraction >2000 μm. Even more distinctly, despite the clay-silt fraction <63 μm is comparable with the other samples, its content of organic carbon of ca. 20 wt.% is about 3 to 6 times higher than the other samples. Considering that the sand size fraction is almost entirely made up of volcanic glass and lapilli, the excess of C_{org} must be contained in the silt-clay grain size fraction. This suggests that the high C_{org} can be attributed to the presence of soot particles. It is also relevant to point out that similar orange bands are present in alluvial Middle Pleistocene slack water deposits in the Grotta della Beata Vergine Cave at Frasassi, and in that case the bright orange color is due to the presence of oxidized vegetal remains (Pignocchi and Montanari [3]).

Discussion: For more than 15 years now, there has been an intense controversy in the Earth science community, which lately has degenerated into a vexing diatribe, about the causes of the Younger Dryas cooling event, which occurred from ca. 12,900 to ca. 11,700 years ago toward the end of the last glacial period in the northern hemisphere, with an abrupt and drastic freezing over a time interval of a few decades. This represents more or less an instant glaciation, causing the extinction of the upper Pleistocene megafauna and a bottleneck in the evolutionary expansion of *Homo sapiens*. The controversy was ignited by Firestone et al., in 2007 [4], who sustained that the primary trigger for the Younger Dryas cooling event was an elusive meteorite impact, which caused an immediate alteration of the global climate. This hypothesis was criticized in the following years by a number of specialized impact geologists (e.g., [5], [6], and references therein), as the proposed evidence for impact was not in agreement with known impact signatures, and who instead advocated the hypothesis of a volcanic eruption as the cause of the Younger Dryas dramatic event. This controversy is somewhat reminiscent of the controversy that started in 1980 after the publication of Alvarez et al. [7] between the "Bombardiers" and the "Detonators" about the causes of the mass extinction (including the infamous dinosaurs) at the end of the Cretaceous Period, with the former invoking a giant meteorite impact, whilst the latter preferred to call upon exceptional volcanic activity in the Deccan Traps, India.

Recently, Reinig et al. [2] synchronized the Younger Dryas cooling event with the explosion of the super-volcano Laacher See in central Germany finding abundant burned-tree remains dated at 13,006 yr BP associated with volcanic ejecta in a number of lacustrine deposits throughout northern European and southern Alpine regions. The burned trees were attributed to immense forest fires, which were ignited by the explosion of the Laacher See volcano. Sun and coworkers [6] also proposed that the ca. 150-years-delay of the Younger Dryas event, which occurred ca. 12,850 years ago, in respect to the Laacher See eruption, was due to the fact that the forest fires produced an enormous amount of CO_2, which, associated with the volcanic degassing, triggered a greenhouse effect.

The rapidly increasing temperature of the Earth's surface would have accelerated the melting of Arctic ices, which eventually would have caused a collapse of the thermohaline circulation in the North Atlantic Ocean, with consequent immediate freezing of the northern hemisphere land masses. This hypothetical scenario is nevertheless scary inasmuch it somewhat reflects the present climate change debate, with the difference that in the Late Pleistocene the trigger for the Younger Dryas freezing event was a natural yet exceptional phenomenon such as a volcanic explosion, whereas for the present global warming situation the trigger was a non-natural yet exceptional human phenomenon, i.e., the Industrial Revolution. Further geochemical and geochronological analyses of the speleo-stratigraphic record of the Grotta dei Baffoni Cave, currently in progress, will hopefully give new insights on the reconstruction of the events that occurred around the Younger Dryas.

References: [1] Montanari A. et al. (2022) *GSA SP 557*, in press. [2] Reinig F. et al. (2021) *Nature, 595*, 66-68. [3] Pignocchi G. and Montanari A. (2016) *Riv. Sci. Preist. LXVI*, 143-180. [4] Firestone R. B. et al. (2007) *PNAS, 7548*, 1-6. [5] Pinter N. et al. (2011) Earth-Sci. Rev., 106, 247–264. [6] Sun N. et al. (2020) *Sci. Adv., 6*, 1-9. [7] Alvarez L. W. et al. (1980) *Science, 208*, 1095-1108.