

Description of Additional Supplementary Files

File Name: Supplementary Data 1

Description: Soil physicochemistry. The physicochemical parameters, and measurement units for pooled soil samples across each cave and zone are specified.

File Name: Supplementary Data 2

Description: Biomass estimates. 16S rRNA gene copy number normalized to both wet weight and dry weight are shown for each sample used in metagenomic sequencing, including extraction controls.

File Name: Supplementary Data 3

Description: Taxonomic diversity. a, Nearest Taxonomic Unit (NTU) table showing quality trimmed counts for each sample. b, observed and estimated richness (Chao1) for each sample. c, relative abundance summaries at phylum level across all samples.

File Name: Supplementary Data 4

Description: Metagenomes and MAGs. a, Sequence statistics and NCBI accessions for metagenomes of this study and those derived from public data. b, Metagenomic short read annotation. c. Taxonomy, functional annotation, relative abundance and NCBI accessions of metagenome assembled genomes (MAGs).

File Name: Supplementary Data 5

Description: Gas oxidation rates and fluxes. a, *In situ* trace gas soil to atmosphere fluxes for equilibrium and transient rates. b, *Ex situ* trace gas oxidation rates and cell specific power calculations. c, Legend for units in sheet b.

File Name: Supplementary Data 6

Description: Oxidic slurry nutrient assays. Uptake and accumulation rates of nitrogen and sulfur species for samples across limestone and basalt caves.

File Name: Supplementary Data 7

Description: Carbon fixation rates. a, ¹⁴C radioisotope labelling data for bulk soils normalised to cell specific rates comparing cave and entrance sites. b, Estimates of methane carbon assimilation rates derived from *ex situ* studies. c, Culture based natural isotope measurements. d, Random Forest driver analysis