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From acid rain to the Anthropocene: 37 years of BIOGEOMON. Part 2 – scientific advances

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Abstract The 11 BIOGEOMON (International Symposium on Ecosystem Behaviour) conferences span 37 years of research in ecosystem science. In this set of papers, we discuss the history of BIOGEOMON in two parts. In Part 2 we consider the development in understanding of three topics over successive conferences: acid deposition, peatland biogeochemistry, and isotope geochemistry. Using these three topics as examples, we show how the BIOGEOMON conferences both reflect, and lead, advances in biogeochemistry research. Using published papers from conference special issues, conference proceedings, and other publications from BIOGEOMON delegates, we highlight the changing importance of these research strands over the years, and consider the questions, insights, and surprises, played out in the meetings.

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Three topics over time

The BIOGEOMON conferences[1] are notable for their inclusiveness, collegiality, and longevity, but the central focus of BIOGEOMON is always the science. In Part 2 of these paired papers (for Part 1 see Dise et al. 2025), we consider how three scientific topics—acid deposition, peatland biogeochemistry, and isotope geochemistry—have evolved over time through the lens of the conferences. We use published conference papers, oral presentations from conference proceedings, and related publications from BIOGEOMON attendees as our research material. Recognising that our choices are a small portion of what was presented and discussed over the years, we nonetheless hope they give an impression of how BIOGEOMON reflects, and leads, advances in the field.

Acid deposition

The BIOGEOMON conference series (Appendix 1) was born out of the acidified streams and dead forests

[1] Although the meetings are officially 'symposia', we refer to them in this paper as 'conferences', in line with their usual designation among participants.

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of the Black Triangle region. By the 1980s, spruce dieback, or 'Waldsterben', had impacted more than 1000 km^2 of forests in the border area between Germany, Poland, and the Czech Republic (Schütt and Cowling 1985; Moldan & Dvořáková 1987). The end result of unchecked industrial air pollution, the 'fishbone trees' of the Black Triangle region were an unmistakable call to address the causes and consequences of extreme acidification.

Forest decline was the second wave of widely-publicised acid deposition impacts. The problem had been recognised for more than a decade previously, through acidification of soft water lakes and streams in Scandinavia and northern North America (e.g. Wright and Gjessing 1976). In response to these reports, legislation such as the US Clean Air Act (US EPA 1970), the United Nations Economic Commission for Europe (UNECE) Convention on Long-range Transboundary Air Pollution (UNECE 1979) and the UNECE Sulphur Protocol (UNECE 1985) were introduced in the 1970s and 80s. But decades, even centuries, of air pollution meant the problem was not going away anytime soon. When the call came to share knowledge on ecosystem acidification at GEOMON 1987 (Prague 1987(1))[2,3], a large international community was ready to answer.

The first two BIOGEOMON conferences (Prague 1987(1) and Prague 1993(2)) were concerned with the sources, geographic extent, processes, and long-term impacts of acid deposition. Talks focused on the chemical composition of precipitation, long-term monitoring programmes, catchment mass balances, and soil processes of buffering through cation exchange or weathering, sulphate (SO_4^{2-}) retention and release, and aluminium (Al^{n+}) mobilisation (e.g. Probst et al. 1995; Manderscheid et al. 1995; Forsius et al. 1995; Urban et al. 1995; Hall et al. 1993). The concept of the 'critical load' (Nilsson and Grennfelt 1988) as a policy tool for regulating gaseous pollutant emissions and assessing recovery was introduced (Hall et al. 1993), and catchment manipulation experiments on major acidification drivers had been established, including liming, clearcut, drought, and sulphur (S) and nitrogen (N) addition and removal (e.g. Lamersdorf 1993; Feger 1995; Uddameri et al.1995; Reynolds et al.1995).

Many models of soil, freshwater and catchment acidification were introduced and discussed in these two meetings, bearing imaginative names like Trickle Down, PULSE, MAGIC, PROFILE, NAP, TAME, and SAFE (Schnoor and Nikolaidis 1987; Carlsson 1987; Norton et al. 1987; Alveteg et al.1995; van Oene and Ågren 1993; Schnoor et al. 1993; Sverdrup and Warfvinge 1993). Models applying to acid deposition research, and many other research fields, have featured extensively over the course of the BIOGEOMON meetings. They generally fall into three types: (1) empirical models (e.g. regressions or classification trees) where the underlying processes are not assumed, (2) steady-state models where only the final state is described, and (3) dynamic models where calculations of time-dependent underlying processes are defined, so that the gradual chemical response of a receptor (soil, surface water, etc.) can be simulated (Forsius et al. 1998). The three types of models are useful for different applications and requirements: both the complexity and input data requirements, as well as the level of detail of the model outputs, increase from empirical to steady-state to dynamic models.

As S deposition began to decline dramatically in the 1990s (Grennfelt et al. 2020) the issue of N deposition became increasingly prominent, ushering in the 'nitrogen years' of the late 1990s and early 2000s. Reflecting this, many acid deposition talks and papers presented at Villanova 1997(3) and Reading 2002(4) described research on the retention, saturation, forms, isotopic tracing, and critical loads of N (e.g. Emmett et al. 1997; David et al. 1998; Harriman et al. 1998; Sickman and Melack 1998; Forsius et al. 2002; Lepistö et al. 2004; Schleppi et al. 2004).

Both nitrate (NO_3^-) and ammonium (NH_4^+) are acidifying compounds, but they can also act as nutrients (Pregitzer 1997; Forsius et al. 2002; Galloway et al. 2003; Frey et al. 2024). As a vital nutrient, N can be strongly retained in the ecosystem (e.g. Pirainen et al. 1998; Lepistö et al. 2004) and is closely linked with the carbon (C) cycle (e.g. McDowell et al. 1998; Curtis et al. 2004). Increasing net primary productivity from elevated N deposition can increase C sequestration and ultimately soil C storage, resulting in a negative feedback to the global C cycle (Goodale

[2] The general use of 'BIOGEOMON' in this paper also includes the first GEOMON conference in 1987.

[3] We use the convention 'City year (conference number)' to denote the different meetings.

2014). Conversely, N deposition to wetlands and riparian zones, either directly or via lateral flow from the surrounding catchment, can increase the emission of nitrous oxide (N_2O), a powerful greenhouse gas (GHG) (Dise and Gauci 2002; Zhu et al. 2013; Pärn et al. 2018).

Recovery from acidification, and delays in recovery, also emerged as research topics in the late 1990s, featuring prominently at Villanova 1997(3) and Reading 2002(4) (e.g. Driscoll et al. 1998; Moldan et al. 2004). Ecosystem chemical recovery often lags a reduction in acid deposition (e.g. Driscoll et al. 1998; Lajtha and Jones 2013): among other reasons, (1) there may be a 'pollution burden' of acids or metals stored in the soil and vegetation (Akselsson et al. 2008), (2) the decline in precipitation acids may be accompanied by a reduction in the flux of nutrient base cations such as calcium (Ca^{2+}) and magnesium (Mg^{2+}) (Lajtha and Jones 2013), and (3) organic acid release or forest re-growth can introduce new acidity into the ecosystem (Evans et al. 2008; Hruška et al. 2017). Finally, the development of new techniques that allowed increasingly detailed investigations of biogeochemical processes was reflected in talks on the response of the rhizosphere and soil microbes to soil acidification and N enrichment (e.g. Pregitzer 1997; Chang 1997; Prosser 2002; Nilsson et al. 2002).

The mid-2000s to early 2010s continued the theme of interlinked cycles and drivers, with research presented at Santa Cruz 2006(5), Helsinki 2009(6) and Northport 2012(7) on topics such as the interactions between acid deposition and GHG emission, climate change, biodiversity, and multiple element cycling (e.g. Kernan et al. 2006; Limpens et al. 2009; Dise 2012). 'Is everything connected to everything else?' (Evans et al. 2006b) is an apt title for this period. Around this time, the impact of humans on nutrient stoichiometry was clearly shown in a shift reported from N limitation to P limitation in many terrestrial ecosystems, due to chronically elevated N deposition (e.g. Akselsson et al. 2008; Crowley et al. 2012). Despite strong reductions in SO_4^{2-} deposition and progress in reducing NO_3^- deposition, ammonium (NH_4^+) continued to be a significant acidifying component of precipitation in many regions (Lajtha and Jones 2013).

More detailed focus on the processes of recovery uncovered new insights, and sometimes surprises. For instance, widespread observations of increasing surface water dissolved organic carbon (DOC) were reported from across Europe and North America (Monteith et al. 2007; see also Peatland Biogeochemistry section). Initially attributed to a range of causes, a combination of field and laboratory experimentation and regional-scale statistical analyses suggested the main culprit was a decline in soil acidity, which increases the solubility of soil organic C (Monteith et al. 2007; Evans et al. 2008). As S pollution declined, soils that had been previously acidified by acid deposition were slowly returning to their pre-acidified state.

In some cases, DOC increases may simply be due to decreases in soil solution ionic strength, which can also increase humic substance solubility (Hruška et al. 2009). Climate and land-use change also certainly play a role (Laudon 2014), and we must be careful to disentangle DOC concentrations from fluxes (Hruška et al. 2024). However, the strong conclusion is that the rise in surface water DOC, which continues to this day, is at least in part an unexpected result of the success of acid deposition policy. It signals the start of a return to an early twentieth century, or earlier, state of aquatic ecosystems that few contemporary researchers had experienced in their lifetimes.

A prominent theme at Santa Cruz 2006(5), Helsinki 2009(6) and Northport 2012(7) concerned the importance of past acid deposition, including delays in recovery due to legacy sulphur stored in the soil (e.g. Robison et al. 2013) and factors acting synergistically with chronic acid deposition damage, such as increased susceptibility to pathogens or drought (e.g. Oulehle et al. 2013; Szkokan-Emilson et al. 2013). Biological recovery was shown to be often slower than chemical recovery, and in some cases irreversible: a significant physical or chemical change in habitat, loss of biodiversity, or failure of recruitment could make a 'recovered' ecological community significantly different from a 'pristine' one (e.g. Limpens et al. 2009; Gundersen et al. 2017). Facing such physical, chemical, and biological hysteresis, how do we define recovery?

A major focus at the most recent conferences (Bayreuth 2014(8), Litomyšl 2017(9), Tartu 2022(10), San Juan 2024(11)) has been evaluating long-term records, and revisiting field manipulation experiments set up decades earlier (e.g. Meesenburg et al. 2014; Frey et al. 2024; Oulehle et al. 2012a). There is continued interest in interactions between acidification

and other stressors, including climate change and ozone (e.g. Bragazza 2014; Karlsson et al. 2017), and on the wider ecological impacts of acidification, such as community shifts (e.g. Vrba 2014; Gundersen et al. 2017; Wieder et al. 2022). Whether long-term elevated N deposition has strengthened or weakened C sequestration and GHG feedbacks is also of considerable interest (e.g. Goodale 2014; Gundersen et al. 2017; Larmola et al. 2022).

Regarding modelling, the dynamic acidification models MAGIC (Model of Acidification of Groundwater in Catchments, Cosby et al. 1985) SMART (Simulation Model for Acidification's Regional Trends, DeVries et al. 1989) and SAFE (Soil Acidification in Forest Ecosystems, Warfvinge et al. 1993) have featured most prominently at the BIOGEOMON conferences over the years. These models all describe the long-term impact of atmospheric deposition on the chemistry of soils and surface waters by simulating critical processes such as vegetation uptake, cation exchange, and weathering. They share the qualities of relative simplicity and measurable parameters, and differ mainly in their applications, with MAGIC more focused on surface water chemistry, SMART on mean soil chemistry, and SAFE on soil chemistry by layer (Sverdrup and Warfvinge 1993). Although they are far from the only models of acidification and recovery that have been successfully used and discussed at BIOGEOMON, these models and their variants are especially notable for their continued importance in research and policy over the decades since their introduction (e.g. Forsius et al. 1998).

Recovery from acidification in North America and Europe remains a strong topic at BIOGEOMON, particularly with regard to the continuing rise in DOC, changing rainfall patterns and other climate influences on recovery, metal release due to changing acid status, and the effect of SO_4^{2-} desorption in delaying recovery (e.g. Akselsson et al. 2014; Meyer-Jacob et al. 2024; Hruška et al. 2024; Navratil et al. 2024; Kopáček et al. 2024; Krám et al. 2024). In contrast, in regions where atmospheric pollution is a more recent problem, such as parts of Asia, Africa, and South America, ongoing ecosystem acidification is a very important issue (e.g. Liu et al. 2014; Curtis et al. 2017; Yu et al. 2017; Sheng et al. 2017).

From opening the eyes of the scientific community to forest death in the Black Triangle, to unraveling the complexities of biological and chemical feedbacks, BIOGEOMON has provided a global stage for acid deposition research. Interest in acid deposition continues to this day, especially regarding long-term ecosystem change, acidification outside Europe and North America, ecological impacts, complex interactions with GHGs and climate, and the dynamics of recovery. However, the focus on acid deposition at BIOGEOMON has gone into a sharp decline from its peak in the 1980s and 1990s, when the topic featured in up to 60% of the presentations (Fig. 1). This mirrors the reduction in acid deposition itself in the countries of most delegates, in response to a wave of ambitious, pivotal legislation curbing the emissions of sulphur and nitrogen oxides. The relative decline in focus on acid deposition is partly due to the overriding interest in climate change and GHG research, but also reflects, in Europe and North America, an environmental success story.

Key acid deposition insights from BIOGEOMON include:

- The BIOGEOMON conference series was initiated in response to the extreme acidification of forests and surface waters in parts of central and eastern Europe. However, by the first meeting in 1987, peak S emission had already been reached in Europe and North America. Consequently, the 'acid deposition' history of the conference has largely been focused on acidification reversal and recovery.
- The 'fishbone' trees of the Black Triangle were primarily killed by direct deposition to vegetation of toxic concentrations of atmospheric sulphur dioxide (SO_2) and metals. Although these impacts of acute air pollution are dramatic and galvanizing, more subtle effects like chronic soil or subsurface water acidification, ecological community shifts, and interactions with other pollutants, nutrients, and climate, are the long-term legacy of acidification.
- Biogeochemical and ecological recovery is often delayed after air pollution reductions, and some changes may be irreversible. This makes the definition of a 'recovered' state challenging.
- The decline in S deposition has left reactive N (primarily NH_4^+ and NO_3^-) as the most important acidifying component of acid deposition. Besides its acidifying effect, N enrichment of wetlands and

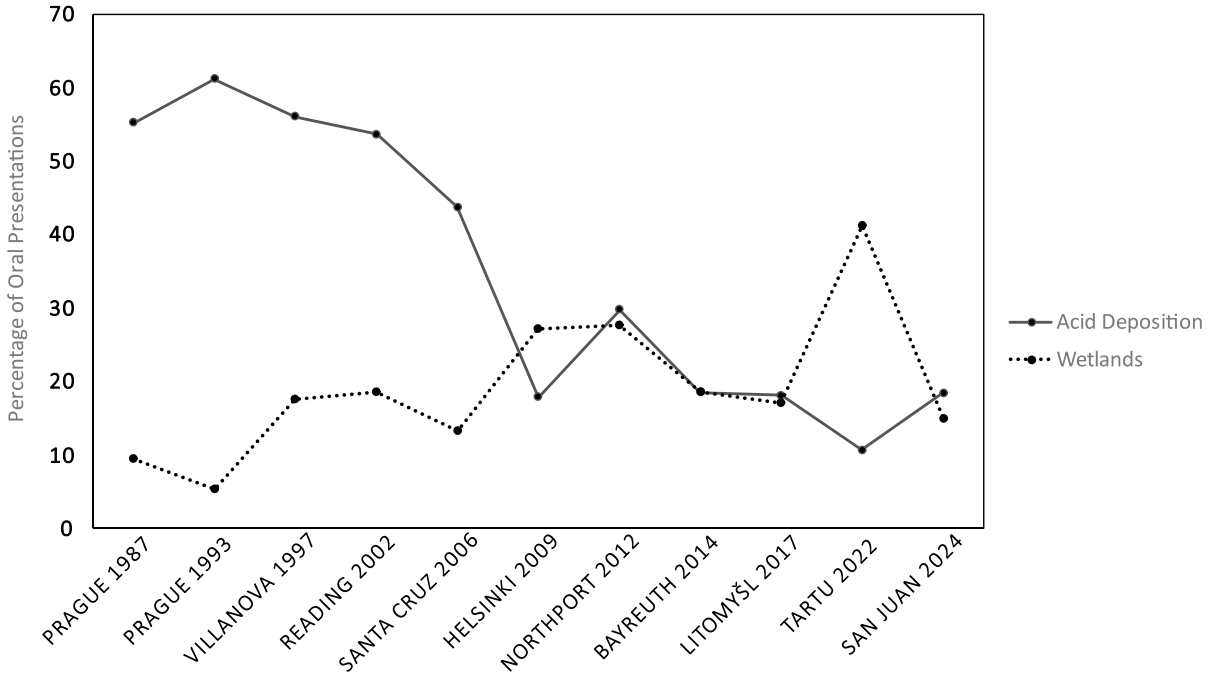

Fig. 1 Percentage of acid-deposition-related and wetland-related talks at the BIOGEOMON conferences

riparian zones can increase the emission of nitrous oxide (N_2O), a powerful GHG. However, N is also a vital macronutrient, and can increase primary productivity, C sequestration and C storage, exerting a climate cooling effect.

- Acid deposition reduction can have unforeseen consequences, such as an increase in surface water DOC.
- The net impact of acid deposition on the global GHG balance is very difficult to assess, but BIOGEOMON has provided a central forum for taking on this challenge.

Peatland biogeochemistry

The topic of wetlands had a meagre start at the beginning of the BIOGEOMON conferences, but, unlike acid deposition, the importance of wetland, especially peatland, biogeochemistry, has increased over time (Fig. 1). Only one talk at the first GEOMON conference in 1987 focused exclusively on wetlands: a presentation by R. Kelman Wieder on the potential effectiveness of man-made *Sphagnum*-dominated wetlands to treat acid coal mine drainage (Wieder & Lang 1984; Wieder et al. 1987). Wieder spoke about the importance of microbial regulation of S biogeochemical processes in *Sphagnum* moss-dominated ecosystems. Such recognition of the central role of biota, particularly microbiota, in biogeochemical processes led to the change in name from GEOMON to BIOGEOMON in 1993. The number of oral presentations featuring wetlands increased to more than 40% in 2022 at Tartu, with the highest proportion of wetland-related talks occurring at the meetings in Estonia, Finland, and Maine (Fig. 1).

Peatland ecosystems have dominated wetland talks at BIOGEOMON, with 90–100% of wetland talks on peatlands in 10 of the 11 meetings (75% in San Juan 2024(11)). There are two main reasons: the value of peatlands as records of past environmental conditions, and their fundamental role in the global carbon cycle as sources and sinks of GHGs.

In the early years of BIOGEOMON many peatland talks focused on using atmospherically-derived chemical species in peat deposits, such as lead and sulphur, to estimate past pollution deposition (e.g. Vile et al. 1995; Urban et al. 1995). Reconstructing the historic picture of pollution, including the 'pristine' state, was very important during this period of

extreme environmental pollution. Indeed, GEOMON began as a monitoring network of stream catchments to characterise inputs of atmospheric pollution in the then Czechoslovakia (Oulehle et al. 2021a; Dise et al. 2025). Monitoring programs were well known to provide information about present day atmospheric deposition of pollutants (Moldan 1991), but less so about historical rates, especially in the former Czechoslovakia during the Soviet era. Dating deposits older than 200 years provided the ability to quantify the state of the environment prior to large-scale industrial expansion.

In the late 1980s and early 1990s, several types of accreting deposits, especially lake sediments (e.g. Norton 1987) were shown to be effective proxies for reconstructing past rates of atmospheric pollutant deposition. Around this same time, *Sphagnum*-dominated ombrotrophic peatlands emerged as a new medium for reconstructing the air pollution history of an area (e.g. Norton & Kahl 1987), with some advantages over lakes. *Sphagnum* mosses are non-vascular plants, and new growth occurs apically from compact structures known as capitula, while older plant material senesces (Clymo & Hayward 1982). Because the rate of organic matter production at the surface of a peat deposit exceeds the rate at which the underlying dead remains decompose, a vertical accumulation of peat results.

For atmospherically-deposited pollutants that are effectively retained and immobilised in surface peat, a vertically accreting peat deposit nicely preserves the record of historical pollutant deposition (Vile et al. 1995). Additionally, since ombrotrophic peatlands are isolated from groundwater and surface water inputs, elements recorded in peatlands with minimal lateral flow can be assumed to essentially come from the atmosphere (Damman 1988). Peatlands served as a proxy for the magnitude of past pollution, particularly in countries where those data were either not available or not easily obtainable.

Reflecting the early focus on acidification, the second conference (Prague 1993(2)) featured a plenary lecture by Kelman Wieder on the role of S cycling in *Sphagnum* peatlands exposed to exceptionally high inputs of S from acid coal mine drainage (Wieder and Taddeo 1993). Three additional presentations on peatlands were published in the special issue of *Water, Air & Soil Pollution* (Vol 79, 1995), and spanned three of the four sections in the special issue: 'Part I: Monitoring', including a paper on capturing the footprint of atmospheric pollution by capitalising on the unique properties of *Sphagnum* described above (Vile et al. 1995), 'Part II: Catchment Manipulations and Biogeochemical Studies', with a paper on cation retention and mobility in an ombrotrophic bog (Urban et al. 1995), and 'Part III: Isotopes as Tracers', including a paper on using S isotopes to model S deposition to peatland soils (Morgan 1995).

The theme of the fourth section in the special issue was 'Modeling' and, since Morgan (1995) modelled excess S deposition using stable isotopes, peatland research encompassed all four of the topics published from the meeting. The recognition of combining expertise from different disciplines (in this case, isotopes and modelling) helped to unravel mechanisms of peatland acidification and began the multi-disciplinary approach that is no longer a novel tactic, but an absolute necessity today for understanding the bigger picture.

By the late 1990s the science taking place within peatlands, and hence questions being asked at BIOGEOMON, shifted from historical reconstructions of pollution towards their important role in the global C cycle as both a long-term C sink and a source of GHGs. This transition was neatly seen in the topics of the two keynote presentations at Villanova 1997(3): the historical development of scientific understanding of peatland acidification given by Eville Gorham (Gorham 1997), and the effect of warming and nutrients on methane (CH_4) emissions from arctic tundra presented by Ann Giblin (Giblin et al. 1997). Leon Lamers linked the two themes together, describing research on the impact of decades of acidic S deposition on C emissions from peatlands and other freshwater wetlands (Lamers et al. 1997).

Both carbon dioxide (CO_2) and CH_4 fluxes from peatlands featured at Villanova 1997(3) (e.g. Moore et al. 1997; Whalen 1997). At this third meeting, we began to learn of large-scale experimental manipulations of climate-sensitive variables and their impact on GHG fluxes in peatland ecosystems. Bridgham et al. (1997) manipulated water table depth and temperature on transplanted peat microcosms in northern Minnesota, while Kelley et al. (1997) reported on flooding impacts at Mer Bleu Bog in Ontario, a research site for which many future manipulations were being discussed at the coffee breaks at the

meeting. The role of soil enzyme activity on GHG emissions from peatlands was also presented, underscoring once again the importance of microbiota to peatland biogeochemical cycling (e.g. Kang et al. 1998).

In the same way as other topics (see, for example, Acid Deposition and Isotope Geochemistry in this paper), the focus of peatland GHG research evolved from quantifying emissions and calculating budgets to understanding processes and interactions. For example, in a keynote talk at Reading 2002(4), the effect of declining S deposition on GHG emissions from peatlands was examined (Dise and Gauci 2002). Notably, CH_4 emissions increase due to a decline in the activity of sulphate-reducing bacteria which competitively suppress methanogenic archaea (Gauci et al. 2002). Further emergence of linkages within and between biogeochemical cycles was evident at Santa Cruz 2006(5) and Helsinki 2009(6) (e.g. Alewell et al. 2006; Roelofs et al. 2006; Hagedorn 2009). Today, interactions between biogeochemical cycles are recognised as important regulators of source-sink functions, not just in peatlands, but in many other ecosystems studied over the 37-year history of the BIOGEOMON conferences.

At the start of the decade, Silver et al. (2001) working in tropical upland soils, and Blodau (2002) working in peatlands, were changing traditional views on what biogeochemical redox processes are possible in anaerobic ecosystems. In Santa Cruz 2006(5), Wieder et al. (2006) presented data that asked peatland ecosystem ecologists to look beyond the two-layered (acrotelm-catotelm) model. This diplotelmic system was originally proposed by the Russian scientist K.E. Ivanov in the twentieth century (Ivanov 1953, 1981), and later modified by Ingram (1978) to define the catotelm as "the permanently anaerobic zone beneath the aerobic acrotelm, to have a water content that is invariable with time, a small hydraulic conductivity, not subject to air entry and hence, is devoid of peat-forming aerobic microorganisms." In his talk, Wieder suggested that the catotelm could at times be considered a 'hot spot' of biogeochemical activity, and propelled peatland scientists to delve deeper into the redox capabilities in this anoxic zone of peat (e.g. Morris et al. 2011).

By Helsinki 2009(6), peatlands had gained sufficient momentum that there was a session dedicated to this topic. 'The Biogeochemistry of Peatlands' thematic session contained 13 oral and 64 poster presentations, in total more than double the number of the next largest session. The session featured keynote talks on nitrogen turnover processes in northern peatlands (Martikainen 2009), and biochemical aspects of peatland restoration (Lamers et al. 2009). Several presentations also reported new information on nutrient partitioning between plants and microbes (e.g. Bragazza et al. 2009). Insights into the major constraints on wetland restoration revealed that the time had come to move away from a trial-and-error approach, which had limited success, and towards an evidence-based approach that sets clear restoration targets, recognising that rehabilitation of all previous wetland ecosystem services may not be possible (e.g. Sallantaus et al. 2009; Urbanová and Picek 2009; Lamers et al. 2015).

Linkages between drivers, and between drivers and impacts, were also prominent at Helsinki 2009(6). Connections between peatland C sequestration and N deposition (e.g. Gunnarsson et al. 2009), and N deposition and peatland vegetation composition (e.g. Limpens et al. 2009) were featured, as well as evaluating the impacts of drainage on N_2O, CH_4 and CO_2 emissions simultaneously (Mander 2009). At Helsinki 2009(6), we learned of the PEATBOG consortium (Pollution Impacts on Peatland Biodiversity, Dise et al. 2009), an international research project linking acid deposition, biogeochemistry, and biodiversity in European peatlands. At Bayreuth 2014(8), an entire session theme, 'Linking Biodiversity and Biogeochemistry', would be dedicated to this connection. At Northport 2012(7), the SPRUCE project (Spruce-Peatland Responses Under Climatic and Environmental Change) examining linkages between warming and other environmental factors was introduced (Sebestyen et al. 2012a). Today, linkages between elemental cycles, environmental drivers, and other relevant ecosystem processes underscore nearly every theme in the BIOGEOMON conferences.

'The Biogeochemistry of Peatlands' would live on as a session theme at Northport 20012(7) but would evolve to 'The Biogeochemistry of Wetlands' at both Bayreuth 2014(8) and Litomyšl 2017(9), reflecting the expanding inclusiveness of other wetland ecosystem types. At Tartu 2022(10), a BIOGEOMON venue where wetlands (mires, swamps, fens, bogs, moors, and coastal and floodplain wetlands) cover approximately 30 % of the Estonian landscape (Mander et al.

2001), there were two sessions dedicated to wetlands, one solely devoted to 'Peatland Processes' and a broader category of 'Biogeochemistry of Lakes, Rivers and Wetlands'. In San Juan 2024(11), a smaller meeting in a tropical setting, one session was dedicated to wetlands, titled, 'Wetland Hydrology & Biogeochemistry.'

Moving chronologically, many of those potential future experimental manipulations to Mer Bleu Bog discussed at Villanova 1997(3) had begun to be reported at Helsinki 2009(6) (e.g. Moore & Ullah 2009). We learned that rewetting drained peatlands, a management strategy designed to increase C storage and reduce CO_2 emission, could result in a higher release of CH_4, a more potent GHG than CO_2 (Estop & Blodau 2009; Urbanová & Picek 2009). Scaling was another emergent topic: given that peatlands vary significantly in several important environmental factors, and often within exceptionally small microscales, it is difficult to extrapolate data to larger ecosystem-level scales. The dynamic behaviour of GHGs, and their dependence on environmental conditions in the face of continued warming and long-term hydrologic change, adds to the complexity of the challenge.

Historically, the focus on peatland C at the BIOGEOMON conferences revolved around GHG fluxes, but peatlands contribute 12 to 20% of the global DOC fluxes, and boreal peatlands account for approximately 58% of total peatland DOC efflux (Rosset et al. 2022). Reading 2002(4) was the first conference to highlight DOC as a session theme, titled 'Soil Organic Matter and DOC', and DOC continued as a focal theme at nearly every subsequent BIOGEOMON.

Stream ecosystems (e.g. Hruška et al. 2009), and forested soils, both temperate (e.g. Borken et al. 2009), and boreal (e.g. Zetterberg 2009) represented most of the DOC research presented in the early conferences, with only a handful of peatland DOC presentations at Reading 2002(4) and Santa Cruz 2006(5) (e.g. Evans et al. 2006a; Clark et al. 2006). Despite not having a session theme dedicated to DOC at Helsinki 2009(6), a record number of talks on DOC were delivered, and we saw a shift away from DOC and acidification towards a coupling of DOC with GHG fluxes in peatlands (e.g. Billett et al. 2009), and other climactic factors such as water table drawdown (e.g. Allott et al. 2009), permafrost melt (e.g. Olefeldt et al. 2009), and drought (e.g. Clark et al. 2009).

At Bayreuth 2014(8), DOC was highlighted in a keynote lecture by Hjalmar Laudon (2014) who spoke about DOC function, dynamics, and regulation in boreal landscapes. The talk discussed the widespread observation of a considerable increase in DOC concentrations and fluxes in many surface waters in North America and Europe since the 1980s, which was hypothesised to be the consequence of recovery of soils from acid deposition (Monteith et al. 2007; also see Acid Deposition section). Laudon (2014) argued, however, that the decline in acid rain is insufficient to sustain the long-term increases in DOC effluxes, so there must be other drivers such as climate and/or land-use change (peatland disturbance). In a session titled 'Controls of DOM fluxes in Ecosystems', presenters spoke about these 'other' drivers influencing DOC export from peatlands (e.g. Giesier et al. 2014). Collectively, sustained increases in DOC fluxes from peatlands may depend on many factors that global climate change will make more difficult to tease apart.

Beginning in Helsinki 2009(6), the role of N_2-fixation in peatland ecosystems as a novel input of new N, and most notably in pristine regions of the globe where atmospheric N deposition was less than 1 kg ha^{-1} yr^{-1}, gained critical traction (e.g. DeLuca 2009). This topic carried throughout the BIOGEOMON series in Northport 2012(7), Bayreuth 2014(8), Litomyšl 2017(9), and Tartu 2022(10) (e.g. Vile et al. 2012, Larmola et al. 2014, Vile et al. 2014, van den Elzen et al. 2017, Larmola et al. 2022). Prior to DeLuca (2009), studies suggested inconsequential contributions of N_2 fixation to the peatland N budget (e.g. Limpens et al. 2006; Markham 2009). Vile et al. (2014) demonstrated rates of N_2 fixation driven by substantial contributions from methanotrophs, and not from cyanobacteria as had traditionally been thought. Methanotrophic N_2 fixation was shown to account for high rates of C sequestration in pristine peatlands and was hypothesized to potentially play an important role in moderating fluxes of CH_4, a question that remains to be answered.

Inputs of N to peatlands through biological N_2 fixation had been largely overlooked for decades due to the incorrect assumption that cyanobacteria are always the dominant N_2 fixers, and to reliance on a technique to measure N_2 fixation, acetylene

reduction assay [ARA], that was developed specifically for cyanobacteria. The ARA assay does not inhibit cyanobacteria N_2 fixation but does inhibit methanotrophic N_2 fixation. When methanogenic N_2 fixation dominates (e.g. Vile et al. 2014), rates calculated using the traditional ARA assay have been grossly underestimated, and the use of $^{15}N_2$ is necessary. These findings transformed our understanding of N cycling in pristine peatlands (Vile et al. 2014, Larmola et al. 2014; van den Elzen et al. 2020). Here is one of the best examples of how stable isotopes helped to advance research on N_2 fixation in peatland ecosystems (see also the Isotope Geochemistry section).

At Litomyšl 2017(9), a session on 'Biogeochemistry of Nitrogen' included talks for the first time on N_2 fixation rates in peatlands that received more than 10 kg N ha^{-1} yr^{-1}. Surprisingly, rates were comparable with those measured in unpolluted peatlands (e.g. Novák et al. 2016; van den Elzen et al. 2020). These findings begged for an evolutionary mechanism to explain why methanotrophs and cyanobacteria would continue to pay the energetic costs to fix atmospheric N_2 given the abundant provision of N in regional atmospheric deposition. No doubt we will continue to explore the fundamental mechanisms regulating N fixation in peatlands, both pristine and polluted, and in a rapidly changing climate, well into the future.

Also, at Litomyšl 2017(9), we saw fresh perspectives from ecosystem warming experiments on CH_4 cycling in northern peatland ecosystems (Keller and Bridgham 2017), and biogeochemical and microbial controls over CH_4 dynamics in wetlands and uplands in Gabon, Africa, a region not previously represented at BIOGEOMON (Bridgham 2017). We continued to hear about DOC under a changing climate (Zeh 2017), a theme that has carried throughout the BIOGEOMON conferences, but perhaps with greater urgency given continued climate warming potentially resulting in enhanced release of DOC.

The 10th BIOGEOMON conference was held in Tartu in 2022, where a plenary talk by Vincent Gauci described CH_4 exchange from tropical trees (Gauci 2022), a novel pathway that may account for some gaps in regional CH_4 budgets. Several peatland talks focused on teasing apart GHG production and consumption processes with the help of isotopic and microbial analyses (e.g. Masta et al. 2022; Ranniku et al. 2022), a set of topics we have seen in prior BIOGEOMON conferences but, once again, here with greater synthesis given the combination of methodological tools. Presentations on topics such as the factors controlling DOC release (Könönen et al. 2022), the composition of microbial communities in tropical peatlands (Espenberg 2022), and vegetational changes under a changing climate in Alaska (Galka et al. 2022) offered new insights into peatland carbon sinks.

The 11th BIOGEOMON conference was held in San Jaun, Puerto Rico in 2024 and was the first in its history to take place in a tropical setting. Reflecting this, 3 of the 13 wetland presentations showcased tropical peat, including talks examining C emissions and N_2O fluxes from tropical swamp forests and peatlands converted to palm plantations (Soosaar 2024; Kasak 2024), and plant–microbe interactions as drivers of ecosystem processes in peat swamp forests (Raczka 2024).

Even in San Juan, however, the focus of wetland talks was still on northern peatland, highlighting the continued importance of these ecosystems in biogeochemistry, as well as the ongoing legacy of the early attendees. Most of the northern peatland presentations focused on the impacts of global climate change (warming, drought, changing hydrology) on C fluxes and storage (e.g. Dise et al. 2024; Mander 2024), reflecting the ever-increasing recognition of the critical importance of peatlands in the global C cycle. San Juan 2024(11) also showcased new peatland-related insights on an original GEOMON topic, mercury (Hg) cycling, using combined methodological approaches such as isotopes, genomics, micrometeorology, and paleoecology, to tease apart the fate of this persistent heavy metal (Bishop 2024).

Non-peatland wetlands

Although peatlands have dominated wetland presentations at BIOGEOMON, the unique and important roles of other wetland types have also been highlighted. For example, Santa Cruz 2006(5) featured several presentations on redox-sensitive biogeochemical processes in riparian wetlands (e.g. Mander et al 2006). The bulk of these riparian talks was focused on N removal via gaseous fluxes.

At the same conference, there was a variety of presentations from the tidal community—both freshwater tidal and salt marshes. The observation that

these marshes can, to some extent, migrate shorewards in response to climate change-induced sea level rise was the focus of research on both ecosystems, but for freshwater marshes, the novel influx of salt to historically freshwater-only systems began to be addressed (e.g., Weston et al. 2006). By Tartu 2022(10), two plenary talks were dedicated to tidal wetlands: restoration of tidal wetlands in the San Francisco Bay (Baldocchi 2022), and CO_2 and CH_4 fluxes from both tidal and non-tidal restored wetlands (Tringe 2022). In salt marshes, denitrification and N_2O production dominated biogeochemical inquiries at BIOGEOMON as early as Santa Cruz 2006(5) (e.g. Liu et al. 2006).

The last 10–15 years have seen a focus on microbial community drivers of ecosystem change, as molecular toolboxes have evolved and advanced. For some time now, we have had the ability to quantify the composition, diversity, and activity of soil microorganisms using state-of-the-art molecular techniques (e.g. Waldrop 2006), to apply an expanding set of non-traditional isotopes to gain insights into biogeochemical drivers of nutrient imbalances (e.g. Novák et al. 2024), and to address emerging climate stressors such as drought (e.g. Clark et al. 2009), warming (e.g. Dise et al. 2024), and wildfire (e.g. Midgley 2024). We have considered the importance of these drivers and their impact on C storage in wetlands ranging from Patagonian peatlands, to marshes, to boreal and arctic ecosystems. Given the importance that wetlands, and especially peatlands, have played over the last 37 years of BIOGEOMON conferences, these ecosystems will undoubtedly continue to play a central role in future meetings.

Key peatland science insights from BIOGEOMON include:

- Peatland ecosystems have dominated the wetland talks delivered at the BIOGEOMON conferences in part due to their value as records of past environmental conditions, their fundamental role in the global carbon cycle, and the research interests of the early organisers.
- In the first few BIOGEOMON conferences, peatlands were shown to be excellent repositories for historical reconstructions of atmospheric heavy metal deposition.
- Global peatlands contain substantial quantities of C (25–30% of global soil C is stored in peat) but their ability to continue to function as a net sink for atmospheric C is threatened by ongoing climate change.
- As the developed world reduced acid precipitation, many in the scientific community turned their research focus toward climate change, and subsequently to GHG emissions from peatlands. Many GHG drivers have since been examined, such as drought, wildfire, temperature, hydrological changes, and changes in N and S deposition. Despite methodological advances at both the microscale and macroscale, we continue to face large uncertainties on the controls over GHG emission from peatlands.
- Interest in non-peatland wetlands has been increasing at BIOGEOMON, especially regarding riparian wetlands, tidal wetlands, and the restoration of wetlands that have been subjected to agricultural drainage. The goal of restoration is not necessarily a return to a 'pristine' previous state, but to at least achieve a functioning wetland with some semblance of previous ecosystem services.
- The most recent BIOGEOMON conferences have shown that the important topics in peatland biogeochemistry don't disappear, they return over the years with more detail, more insight into processes, and greater appreciation of biogeochemical and ecological linkages and connections.

Isotope geochemistry

Data on abundance ratios of isotopes provide a type of concentration information that is independent of bulk concentrations. Isotope ratios are useful in two types of biogeochemical investigations: they serve as a diagnostic tool capable of identifying specific processes in black-box studies, and they are useful tracers of the origin and dispersion pathways of environmentally-relevant elements. Knowledge of the direction and magnitude of isotope fractionations is central to both of these applications.

Isotopes have featured as Thematic Sessions in 7 out of 11 BIOGEOMON conferences, the most of any methodological topic (Dise et al. 2025). Additionally, as the scope of natural abundance isotope studies, radioactive isotope applications, and isotope-labelling

experiments broadened, many other BIOGEOMON sessions became interspersed with isotope-based contributions.

Sulphur dominated the isotope presentations at early BIOGEOMON meetings (e.g. Finley et al. 1995; Prietzel et al. 1995; Mörth and Torssander 1995; Groscheová et al. 1998; Novák et al. 2004), since S was the main culprit behind surface water acidification and forest dieback. Sulphur isotopes proved valuable in tracing the fate of S from the atmosphere to soils, vegetation, surface water, and groundwater, including its source, retention, residence time, and release from various ecosystem components. The use of $\delta^{34}S$ has also allowed researchers to better constrain estimates on recovery rates from acidification and identify the dynamics and fate of S over the recovery period (e.g. Shanley et al. 2008).

Among heavy metal isotopes, lead (Pb) has also been well-represented at BIOGEOMON (e.g. Vile et al. 1995; Fowler et al. 1998; Chillrud et al. 2004; Conkova and Kubiznakova 2008; Martinkova 2024). Lead is an important topic in biogeochemical research due to its toxicity, and the significant human disturbance of its cycle. The absence of measurable isotope fractionations that could obscure source signatures at the receptor site also makes Pb isotopes valuable tools for differentiating among various sources of Pb (e.g., coal combustion, vehicles, historical smelting), and for determining fluxes and transformations of this metal in a wide range of ecosystems.

Lead isotopes in regionally-collected peat cores drew the community's attention to coal incineration in power plants as a massive source of atmospheric Pb pollution (Novák et al. 2003), at a time when traffic-related emissions were the principal focus of environmental Pb studies. At the most recent BIOGEOMON, San Juan 2024(11), Pb isotopes were used to pinpoint the fine-scale distribution of sources of lead to urban air, including coal combustion, local or regional-scale mining activities, recycling and waste incineration, household heating, and traffic (Martinkova 2024).

Isotope dynamics along the anthropogenic N cascade (Galloway et al. 2003), essential to identify the sources, contributions, and transformations of this nutrient/pollutant, have been well represented throughout the four decades of BIOGEOMON (e.g. Gebauer et al. 1994; Buzek et al. 1998; Rock and Mayer 2004; Shanafield et al. 2010; Sebestyen et al. 2012b; Oulehle et al. 2021b; Redling et al. 2013). Insights into the rate of denitrification can be obtained by studying N and O isotopes of N_2O (Goldberg et al. 2010; Amundson et al. 2023), and biological nitrogen fixation in organic soils can be determined by $^{15}N_2$ labelling incubation experiments. As described in the Peatland Biogeochemistry section, recent findings indicate adaptation of N_2 fixers that were normally thought to be active only in low N deposition areas (e.g. Vile et al. 2014) to atmospheric inputs of pollutant N (van den Elzen et al. 2018; Štěpánová et al. 2023). This surprising finding was only made possible with the use of ^{15}N isotopes.

Oxygen (O) and hydrogen (H) isotopes have featured in BIOGEOMON in numerous hydrological and hydro-biological studies, including quantifying residence times of water and pollutants, estimating rates of photosynthesis and respiration, and tracing ecological processes (e.g. Buzek et al. 1995; van Donkelaar et al. 1995; Houle et al. 2004; Chomicki and Schiff 2008; Miles et al. 2012). Oxygen in association with S or N, either singly or in a dual isotope approach, provides added potential for investigating the sources, sinks and transformations of elements in the biosphere (e.g. Mörth and Torssander 1995).

Isotopes of other elements have appeared throughout BIOGEOMON. As early as Prague 1993(2), Göran Åberg showed that strontium (Sr) isotopes could be used to monitor environmental change over a wide range of ecosystems and time periods (Åberg 1995), work that helped trigger worldwide interest in catchment-level Sr systematics. Cosmogenic ^{10}Beryllium (Be) was proposed by Kelman Wieder and colleagues in Helsinki 2009(6) as a method of dating peat cores, with Be having several advantages over the more traditionally used ^{210}Pb isotopes (Wieder et al. 2010). At the same meeting, bioaccumulation by wetland plants of ^{238}Uranium (U) was shown by Fernando Carvalho and colleagues as an effective secondary treatment of chemically-treated U mine water (Carvalho et al. 2011).

The advent of multi-collector ICP mass spectrometry in recent decades resulted in increased interest in non-traditional isotopes at BIOGEOMON meetings (Fig. 2). The storage, release, and impacts of numerous toxic trace metals and metal nutrients can now be investigated using stable isotope ratios (e.g. Novák et al. 2024; Landis et al. 2024; Schmitt et al. 2012; Farkas et al. 2013; Andronikov et al. 2021). For example, at Litomyšl 2017(9), talks included the

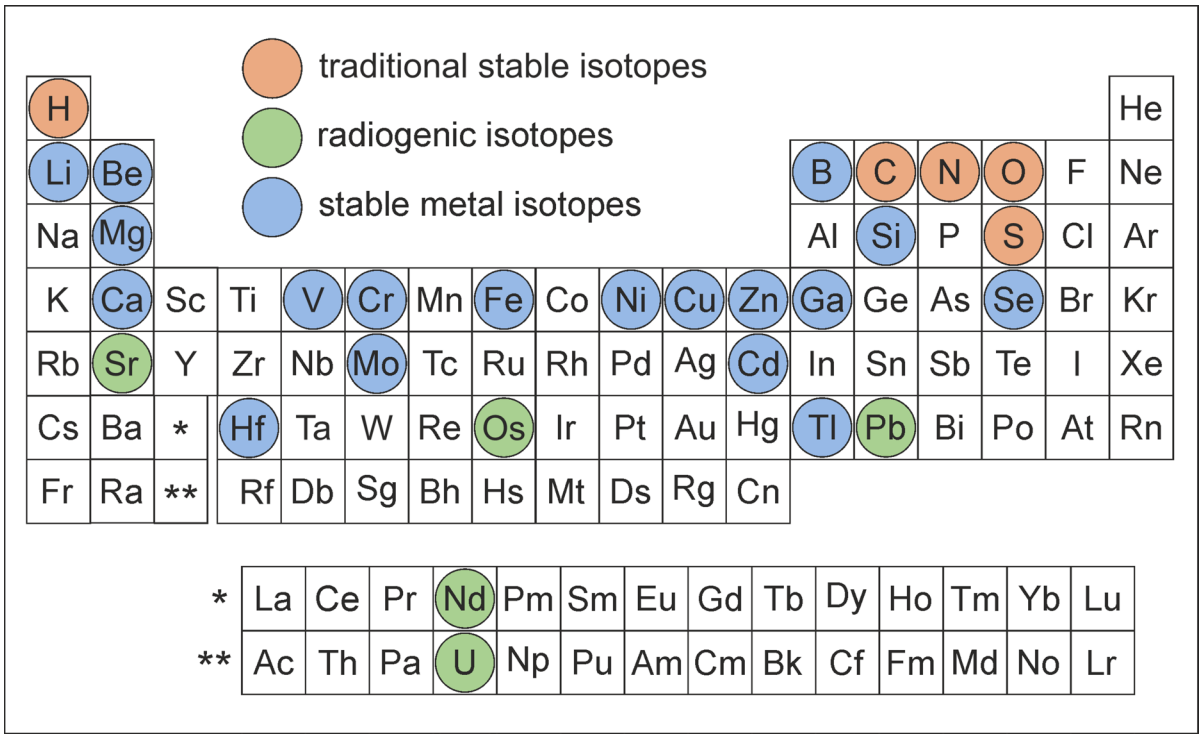

Fig. 2 Overview of chemical elements with isotopes used in environmental and biogeochemical studies. In early BIOGEOMON conferences, only light elements (H, C, N, O, and S) along with Sr and Pb were covered. Recently, meeting contributions also focus on metal isotopes

use of isotopes of boron (B) to distinguish sources of NO_3^- and PO_4^{3-} in surface waters (Mayer et al. 2017), lithium and U to quantify abiotic weathering processes (Hindshaw and Tipper 2017; Steinhoefel et al. 2017), and gallium (Ga) as an analogue for tracing the sources and sinks of the monoisotopic element Al (Chen et al. 2017).

In line with other disciplines, there has been a shift from pollution to a climate-change focus in isotope geochemistry research at BIOGEOMON (e.g. Robertson et al. 2004; Zhu et al. 2013; Gebauer 2022). Just like hydrochemical budgets of nutrients and pollutants, GHG budgets can be constrained by using isotope mass balances. When isotope fractionations are well understood, the origin of trace gases can be identified; for instance, isotopically light C in CH_4 signifies biogenic sources, in contrast to the isotopically heavy C of geogenic CH_4 (e.g. Humez et al. 2016). Sources and sinks of CH_4, CO_2, and N_2O are now some of the most dynamic themes of BIOGEOMON conferences (e.g. Masta et al. 2024). Complex interactions (e.g. Gebauer 2022) and revisiting long-term isotope addition experiments (e.g. Veerman et al. 2020) also feature in more recent conferences.

Focus on: $\delta^{34}S$ in the GEOMON catchments

Input–output mass balances in small catchments to assess ecosystem health have always belonged to the core themes of BIOGEOMON (Dise et al. 2025). Multiple-catchment studies along gradients of pollution, bedrock chemistry, and climate provide valuable insights into ecosystem processes. One of these, the GEOMON network of headwater catchments in the Czech Republic (Oulehle et al. 2021a) provided the scientific foundation for the original GEOMON conference, and has been expanded and continued to this day.

Figure 3 shows S isotopic ratios from different ecosystem components in the GEOMON catchments (Fig. 3A) along a pollution gradient. The sites are underlain by a variety of crystalline bedrock types differing in the abundance of microbially-accessible sulphide (S^{2-}) (Novák et al. 2005). This part of

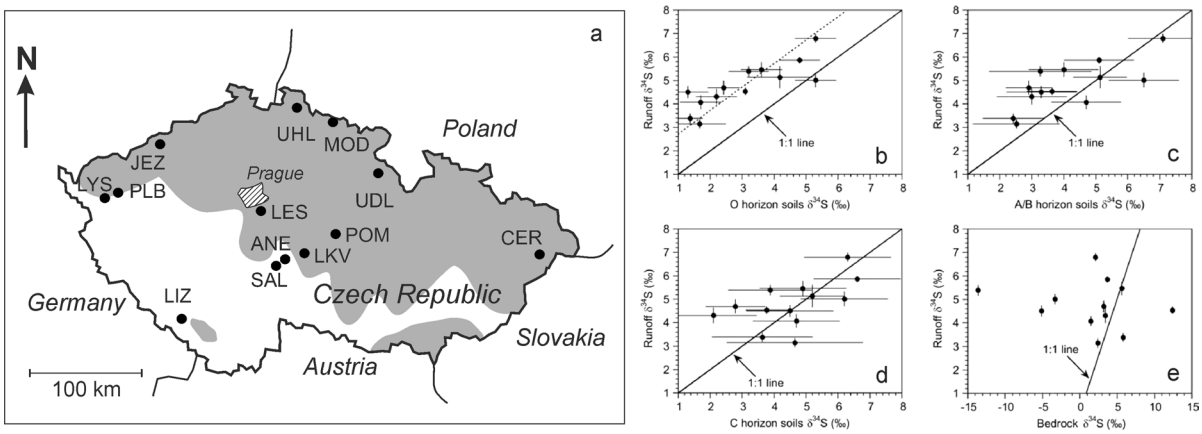

Fig. 3 S isotope study of catchment pools and fluxes along a strong pollution gradient in the Czech Republic. (**A**) Location of GEOMON study sites. Shading indicates approximate regions of average bulk S deposition: dark gray >10 kg S ha^{-1} yr^{-1}, white <10 kg S ha^{-1} yr^{-1}. Note that throughfall S deposition can be 2 or more times bulk deposition. Bulk and throughfall S deposition are highest along the northern borders with Germany and Poland. (**B**-**E**) Site-to-site correlations between $\delta^{34}S$ (per mil; mean ± standard error) in runoff and $\delta^{34}S$ of: (**B**) soil O horizon, (**C**) A/B horizons, (**D**) C horizon, and (**E**) bedrock. The dotted line in **3B** indicates the average isotopic offset between the O horizon and runoff. The offset is smaller in the A/B horizons and is not statistically significant in the C horizon. No error bars are shown for bedrock $\delta^{34}S$ (**E**); these were measured on a single composite sample, and thus uncertainty estimates are unavailable. Modified from Novák et al. 2005

Central Europe has been known for a strong gradient in industrial S pollution, with a highly polluted north ("Black Triangle"; spruce throughfall input in the late 1980s of over 130 kg S ha^{-1} yr^{-1}), and relatively unpolluted south (Oulehle et al. 2017 and references therein). Water, soil, and bedrock samples were collected in 1997, 10 years after peak S emission rates, and S deposition had dramatically declined from 1980s levels. However, the flux of S in runoff (primarily as SO_4^{2-}) was still extremely high: up to 3 times the atmospheric S input. The question was, why wasn't the streamwater SO_4^{2-} flux mirroring the decline in SO_4^{2-} deposition?

Sulphur isotope fingerprinting provided the answer. Across the sites, there was a positive correlation between the $\delta^{34}S$ values of runoff and those of the soil, particularly the deeper layers (Fig. 3B-D), and no correlation between the $\delta^{34}S$ of runoff and bedrock (Fig. 3E). The $\delta^{34}S$ values indicate that S in runoff was mainly derived from the anthropogenic S pool in deeper soil layers (primarily the C horizon, Fig. 3D) where industrial atmospherically-deposited S from the peak pollution years was stored. This led to the important conclusion that the "excess" S in runoff originated from legacy industrial S (Novák et al. 2005).

The $\delta^{34}S$ study in the GEOMON catchments also provided new scientific understanding of the processes of S storage and cycling in catchments. Early models predicting rates of recovery from acidification generally only considered adsorption and desorption of inorganic SO_4^{2-} as the mechanism of soil S retention (e.g. Driscoll et al. 1998; Hruška & Krám, 2003). However, S can also be microbially cycled and recycled, and the kinetics of these biotic processes differ from those of inorganic adsorption (Novák et al. 2005). Therefore, models of recovery based on inorganic adsorption processes are not valid if S cycling is microbially dominated (Novák et al 2005). It was not clear, however, whether microbial S retention was prevalent enough to merit incorporation in the models.

Isotopes again provided an answer to this question for the GEOMON network and other catchments. Unlike SO_4^{2-} adsorption/desorption in soil, which is primarily an abiotic process, microbially-mediated organic S cycling is associated with isotope fractionation (Van Stempvoort et al. 1990). The understanding of the different isotopic effects of these processes allowed the estimation that approximately 60% of secondary sulphate S exported via stream water in the north of the Czech Republic was organically cycled

(Novák et al 2005). Therefore, modelling the recovery trajectory of these catchments, and presumably others, needed to account for both inorganic and organic retention in the soil.

Key isotope geochemistry insights from BIOGEOMON include:

- Isotopes are highly valuable in biogeochemical investigations as they allow researchers to identify the sources, transformations, and fluxes of environmentally-relevant elements.
- The ^{34}S isotope has featured throughout the BIOGEOMON conferences, since ecosystem acidification from extreme SO_2 emissions was one of the founding issues of the conferences. This isotope showed that the SO_4^{2-} in stream water in the GEOMON catchments originated from fossil fuel combustion, identified the subsoil as the main reservoir for legacy SO_4^{2-}, provided insight into the relative rates of microbial S cycling versus inorganic retention, and improved model estimates on recovery rates from acidification.
- Lead isotopes have also featured throughout the conference as they are particularly useful for estimating historical levels of Pb pollution in a wide range of habitats, and for distinguishing between sources such as industrial or household coal combustion, mining activities, waste incineration, and gasoline combustion in vehicles.
- In addition to S and Pb, major ion isotopes prevalent throughout BIOGEOMON include those of N, O, and H. These have more recently been joined by a wide range of trace metals and metal nutrients, which can now be investigated thanks to new technical capabilities.
- Isotopes play an important role in climate change research: they can be used to identify the sources and fluxes of GHGs, and to provide insight into the biological and chemical transformations of these compounds, especially CH_4, CO_2, and N_2O.

Conclusion

The three topics of acid deposition, peatland biogeochemistry, and isotope geochemistry provide examples of how the field of biogeochemistry has advanced over the last four decades, as reflected in the BIOGEOMON conferences. Some common strands run through these themes, such as the fates of excess S and N, feedbacks on GHGs, complex interactions between pollutants and nutrients, and ecological transformations. Although topics have changed in prominence over the years, new insights can arise from research first presented decades earlier and examined in a fresh light, by, for instance, evaluating long-term measurements, revisiting past experiments, or applying novel techniques. We believe that BIOGEOMON's strong foundation of nearly 40 years of biogeochemical research, coupled with adaptability to new environmental challenges, will continue to serve the biogeochemistry community well, especially the future generations of scientists to whom we look to keep BIOGEOMON flourishing.

Acknowledgements We would like to thank all those who have participated in the BIOGEOMON conferences, openly sharing their ideas, discoveries, and questions. Uniting internationally prominent scientists, early and mid- career researchers, and graduate and undergraduate students, across political and social systems, these encounters have enriched the biogeosciences, expanded our understanding of the natural world, and led to lasting collaborations and friendships. We would like to thank Professors Bedřich Moldan and Tomáš Pačes, and their colleagues at the Czech Geological Survey, Prague, for their vision in establishing the GEOMON / BIOGEOMON conferences, and for their continued inspiration to generations of biogeoscientists. We thank other BIOGEOMON stalwarts, in particular Jiří Černý, Kelman Wieder, and Steve Norton, as well as the organisers of each conference, for their dedication to making each meeting a success. We also wish to pay tribute to the many behind-the-scenes helpers with the BIOGEOMON series, and in particular Eva Pačesová and Kimberli D. Scott who were involved in countless ways for decades.

BIOGEOMON has never been associated with a professional organization, and each organising committee has had to take on the challenge of supplementing registration fees with external funds. Private, industrial, government, and educational organisations have all helped fund the meetings.

We dedicate this paper to the new generation of biogeoscientists who will carry the work of environmental research forward. We hope that future BIOGEOMONs will enrich you personally and professionally in a world facing new and complex global ecological challenges.

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Declarations

Competing interests The authors have no relevant financial or non-financial interests to disclose.

Appendix 1

The 11 BIOGEOMON conferences to date, and approximate number of attendees and countries represented

No	Location	Year	Attendees	Countries	Special Issue
1	Prague, Czechoslovakia (GEOMON)	1987	150	20	None
2	Prague, Czech Republic	1993	200	27	Černý et al. 1995
3	Villanova, Pennsylvania, USA	1997	240	28	Wieder et al. 1998
4	Reading, England, UK	2002	300	25	Wieder et al. 2004
5	Santa Cruz, California, USA	2006	300	30	Novák et al. 2008
6	Helsinki, Finland	2009	450	43	Johnson et al. 2010, Mander and Mitsch 2011
7	Northport, Maine, USA	2012	200	18	Johnson et al. 2013
8	Bayreuth, Germany	2014	300	35	None
9	Litomyšl, Czech Republic	2017	300	30	None
10	Tartu, Estonia	2022	170	20	None
11	San Juan, Puerto Rico	2024	140	13	Current volume

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