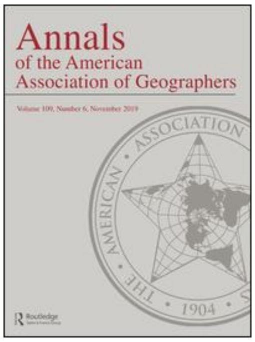

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Synchronizing Earthly Timescales: Ice, Pollen, and the Making of Proto-Anthropocene Knowledge in the North Atlantic Region

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The Anthropocene concept frames an emerging new understanding of the human–Earth relationship. It represents a profound temporal integration that brings historical periodization on a par with geological time and creates entanglements between timescales that were previously seen as detached. Because the Anthropocene gets this role of a unifying planetary concept, the ways in which vast geological timescales were incorporated into human history are often taken for granted. By tracing the early history of the processes of synchronizing human and geological timescales, this article aims to historicize the Anthropocene concept. The work of bridging divides between human and geological time was renegotiated and took new directions in physical geography and cognate sciences from the middle decades of the twentieth century. Through researchers such as Ahlmann (Sweden), Seligman (United Kingdom), and Dansgaard (Denmark) in geography and glaciology and Davis (United States) and Iversen (Denmark) in palynology and biogeography, methodologies that became used in synchronizing planetary timescales were discussed and practiced for integrative understanding well before the Anthropocene concept emerged. This article shows through studies of their theoretical assumptions and research practices that the Anthropocene could be conceived as a result of a longer history of production of integrative geo-anthropological time. It also shows the embedding of concepts and methodologies from neighboring fields of significance for geography. By situating and historicizing spaces and actors, texture is added to the Anthropocene, a concept that has hitherto often been detached from the specific contexts and geographies of the scientific work that enabled its emergence. *Key Words: environmental object, geo-anthropology, glaciology, palynology, proto-Anthropocene.*

The present has proven correct what German historian Koselleck (1979) suggested: There is a coexistence of multiple times. The full implication of this statement has become abundantly clear in the last two decades with the arrival of the Anthropocene concept (Crutzen and Stoermer 2000; Steffen et al. 2015; Zalasiewicz et al. 2018), suggesting new, geo-anthropological temporalities for the human–earth relationship. Proposed starting points of the Anthropocene epoch have ranged from the early Holocene up to almost the present day (Swanson 2016; Warde, Robin, and Sörlin 2017).

Many of the propositions are familiar to geography, where patterns of space have been unavoidably linked to reconfigurations in the understanding of time and the waves of human expansion through agriculture, empires, resource colonialism, and techno-scientific dominance (Ruddiman 2003; Lewis and Maslin 2015; Waters et al. 2016). The potential chronologies following from these by now comprehensive exercises of Anthropocene time-making—"seemingly banal time charts" (Swanson 2016, 172)—have become such a hotbed of arguments because they are, on the contrary, of utmost importance, functioning as "a form of infrastructure that shapes environmental management practices, research agendas, and policy negotiations" (Swanson 2016, 172). For some practitioners of geography, the Anthropocene might even herald a "rediscovery" of its "aspirations to be a 'world discipline' about the human–environment relationship, extending to the largest spatio-temporal scales" (Castree 2014, 449).

The interest in time periods and temporal dimensions has grown not just in disciplines, like the geosciences, that were always preoccupied with the record of time but increasingly across the environmental sciences and in the social sciences and humanities. Through recent research within the lat-

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ter, timescales are widening beyond the confines of historical times to engage with science-based chronologies of geological "deep time," the biological past, and archaeology (Rudwick 2005; Chakrabarty 2009, 2019; Shryock, Smail, and Earle 2011; McGrath and Jebb 2015). This *temporal turn*—the term itself becoming increasingly used in the previous decade (e.g., Hassan 2010; Corfield 2015)—has led to a burgeoning interdisciplinary collaboration in which geographers have provided core articulations (Castree et al. 2014; Yusoff 2016). The Anthropocene soon became the key concept to crystallize the raised sensibilities of this critical interface, undoubtedly because of its major claim that human impacts had reached multiple critical thresholds and scaled to the planetary level in ways that would merit an acknowledged addition to the chrono-stratigraphic record. Even though it is evident that integrative human–geological timescales have permeated recent debates on what impact was major enough to warrant the use of the concept, with the proposed mid-twentieth-century rise of the Great Acceleration as a strong candidate (Zalasiewicz et al. 2015), it is less evident where these timescales came from. Engagement in these debates, including among geographers, who in bibliometric terms are leading users of the concept (Knitter et al. 2019), has somewhat obscured how the Anthropocene belongs in wider processes of temporalization that date further back into the twentieth century.

By following these processes, as we do in this article, we discover not only geographers at work but also interesting fault lines relating to *whether* and *how* different timescales—geological, geophysical, biological, and social—should be aligned. Some researchers, chiefly anchored in geological and geophysical time records, argued for strong alignment in line with what later appeared in Earth system science and eventually crystallized in the Anthropocene mode of thought. Others, typically working on organic time layers of the late Quaternary, tended to prefer a more cautious 'individualistic response,' arguing for less alignment, along the lines of latter-day humanist critiques against the omnibus character of the Anthropocene concept (e.g., Crist 2013; Pálsson et al. 2013). The production of planetary knowledge was always situated in political and scientific geographies that could be scaled up to speak for the entire planet. Lehman (2020), for example, showed how the oceans became an object of knowledge on a planetary scale through geographical work in the field. These kinds of processes, we argue, were not solely about planetary spatiality but also about timescales rendered visible through materialized proxy records and made to speak to an aggregated human–Earth relationship. In this article, the term we use for this kind of complex integrative work on multiple timescales is *synchronization* (Jordheim 2014, 2017), because it denotes the integration of different temporalities across the entire disciplinary spectrum into an emerging geo-anthropological temporality.

Environmental Objects and the Proto-Anthropocene

Our focus is on the North Atlantic region, a limited but essential context where the origination of synchronized timescales cross-pollinated physical geography with neighboring knowledge fields in climate history, earth history, and paleoecology. A key material element in our story is ice and how it turned from a strictly geophysical entity into an *environmental object*. Environmental objects appear as objects of knowledge on different scales through interconnections with their surroundings on both local and, increasingly, planetary levels and with the rate and direction of change in these surroundings (Aronowsky 2018). Ice, in this capacity, was used in stories about the historical geography of the region, linking timescales of ice cores—assembled vertical time—with those of human settlements and impacts in conventional landscapes of time and agency. A second key material is the organic paleolayer where pollen, often distributed and relocated in sediments, contributed further chronogeographical detail and nuances of human agency, hence also problematizing some of the grand narratives that arose from the historical geography of ice.

Geography and geographical practices were present in this research in ways that merit further attention. In the following sections, we focus on a set of loosely connected scholars from Denmark, Sweden, and the United States, whose work and research styles we identify as essential for the early synchronization of disparate timescales in or related to physical geography. These scholars would all become international leaders with defining influence in their fields over long periods of time. That is not the only reason we find them interesting, though. They are selected here because they stand out as ideal types, quintessential representatives, of broader patterns in the intellectual history of the Anthropocene and of an evolution and calibration of methods and ideas that demonstrate how key features of the Anthropocene outlook took shape several decades before the concept was articulated. We call this a *proto-Anthropocene* understanding. We further posit that their work represents several significant contributions in a succession whereby entanglements between human and societal timescales and those of geo-chronologies were gradually established and affected globally through multiple disciplines and subsequently by policy.

Their work covered a half-century, from the 1920s through to the 1970s, with a concentration around the peak of the Cold War in the 1950s and the 1957–1958 International Geophysical Year. This was a period when Fennoscandia and the North Atlantic, including Greenland, attracted a great deal of interest for a combination of strategic and scientific reasons (Doel et al. 2014; Doel, Harper, and Heymann 2016). A cross-cutting theme of the research was climate related, aimed at explaining and describing changes in climate and its impact. The theme ran through issues as far apart as the geographical distribution of vegetation, the retraction of glaciers, the patterns of sea ice, and the causes of the demise of the Norse colony on Greenland in the Middle Ages. All of these questions had strong temporal components, none of which were even remotely known in the early decades of the twentieth century. Geographers and paleoscientists working in the North Atlantic region shared interests in geophysical and biochemical processes and their implications for what was in the course of the postwar decades identified as anthropogenic "environmental change" (Warde, Robin, and Sörlin 2018, 112, 121, 221). They found in the far north attractive sites of inquiry that were accessible despite their remote location. As it turned out, they also produced scientific work that in various ways informed conceptions of anthropogenic transformations on geophysical scales.

Horizontal Gradualism: Glacial Orthodoxy

Scientific curiosity in the region was older (Bravo and Sörlin 2002; McCannon 2012) but received a substantial boost because of the early twentieth-century Arctic warming trend, which saw temperatures between 1919 and 1939 rise several degrees above the earlier average (Yamanouchi 2011). It was during that period that glaciologist Ahlmann initiated his comprehensive studies of glacier reduction across the entire region, from Scandinavian glaciers in the 1920s through to ice sheets on Svalbard and Greenland in the 1930s. A professor of geography at Stockholms Högskola (now Stockholm University), Ahlmann rose to become a prominent international leader of the discipline, a tireless networker and science diplomat, serving as president of the International Geographical Union from 1956 to 1960. After documenting massive glacial retreat across the North Atlantic region, he nonetheless remained stubbornly skeptical to the idea of human climate forcing, reflecting a stand among many field scientists, glaciologists not the least (Sörlin 2009).

His predominantly empirical work style prioritized site-specific field research to monitor glacial change in real time, with digs in the upper snow layers to uncover change over years, possibly decades, but rarely further (Sörlin 2011). Ever anxious to measure ice extent and volume properly, his methodological rigor was impeccable. He used teams of students and close colleagues, supported by assistants who were by trade and tradition bound to field sites that they measured and recorded repeatedly over the course of years. He was assisted by Sami in the Scandinavian North, farmers in Iceland, local Inuit and Norwegian hunters in Greenland, and often by local scientific expertise. He ultimately established a glaciological research station at Tarfala in northern Sweden in 1945, a "microgeography of authority" based on his site-specific monitoring approach (Sörlin 2018).

Ahlmann was well respected, and his meticulous, data-centered work was admired by his international geography peers, such as Seligman and Manley (1944; Endfield, Veale, and Hall 2015). Seligman, himself an avid glaciologist, president of the International Glaciological Society, and author of the much-acclaimed *Snow Structures and Ski Fields* (Seligman 1936), was a loyal supporter of Ahlmann's climate change skepticism (Seligman 1944). Their work in geographical glaciology represented inter- and immediate postwar orthodoxy, just before it was about to be questioned. As much as Ahlmann was an innovative physical geographer, his multisite comparative "horizontal" method—favoring linear and gradualist interpretations of natural

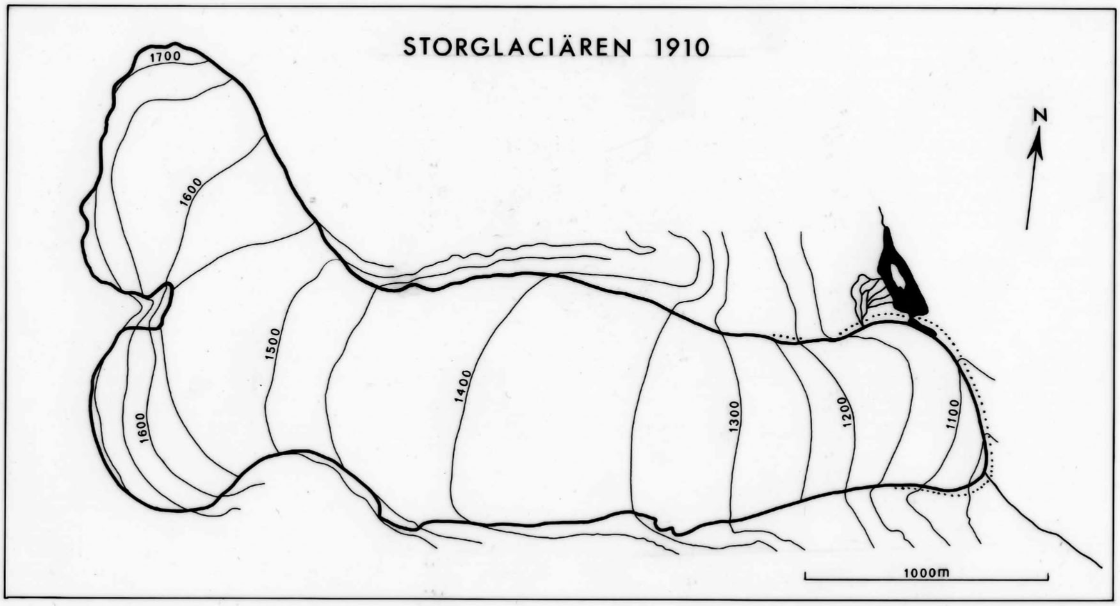

Figure 1. Stylized map of the Storglaciären in North Sweden in 1910 with no timescale. *Source:* Bolin Center for Climate Research, Swedish Glaciers (https://bolin.su.se/data/svenskaglaciarer/glacier.php?g=69). Map based on a photograph by Fredrik Enquist (1910).

variability to explain climate "fluctuations" (his desired term)—kept him outside of the wider systemic approaches to climate and geophysical dynamics that grew among his international contemporaries working closer to fields such as meteorology and climate physics (Fleming 2016; see Figure 1). As a result, he lacked conceptual and theoretical tools to propose explanations or hypotheses that took nonlinear or anthropogenic drivers into account. His research established the reduction of glaciers as a scientific fact, but he spoke timidly on theories of climate fluctuations and their causes (e.g., Ahlmann 1948, 1953).

This cautious outlook did not allow for human agency or timescales in explaining the causes of change. In Ahlmann's rendering, glacial change had little connection with deep time chronologies and it was only loosely related to earlier time-organizing efforts for the late Quaternary period such as the sediment-based "varve" geochronology, proposed by the Stockholm geologist De Geer (De Geer 1912; Bergwik 2014). This succession of dating techniques aspired to overcome the basic shortcoming of geology, that "the history of the earth" had "hitherto been a history without years" (De Geer 1912, 241), but it did so without any deeper reflection on the possibility that this "history" might include the presence and agency of humans. The idea that geological time manifested itself with a high frequency, on the annual scale in both clay and ice, however, opened the door to further reflection on human–geological interaction.

Ahlmann and his field-based contemporaries can be seen as standing on the threshold of a proto-Anthropocene understanding. Based on fledgling research on what had just been termed the *cryosphere* by Polish glaciologist Dobrowolski (1923)—a term resolutely refuted by Seligman and the British establishment (Barry, Jania, and Birkenmajer 2011)—Ahlmann identified ice as an element of geographical change. His epistemic project did not include ice as part of "the environment," a concept he did not use, however, and his work on glacial change contained few ideas about temporalization or the combination of multiple temporalities.

Scale Jumping through Field Jumping: The Portable Cryosphere

In 1966, just about two decades after Ahlmann founded his research station in Tarfala, the Camp Century ice core drill penetrated the thick north Greenland ice sheet to reach solid ground underneath. The drilling produced the deepest ice core—1,387 m—to date. It also served as a validation of the possibilities of ice core drilling that had been expressed by hopeful scientists for more than a decade (Lolck 2004; Langway 2008; Martin-Nielsen

2013; Nielsen, Nielsen, and Martin-Nielsen 2014). Compared to previous ways of measuring change in the cryosphere, the Camp Century ice core offered a drastic temporal expansion, allowing for a climatic record reaching 100,000 years back in time.

This jump in scales, from annual measurements of incremental change in glaciers to millennia of climatic shifts stored inside a single object, allowed new temporalities of ice to materialize and new domains of expertise to take form. In the years following the Camp Century ice core, a vertical geography of the cryosphere (a concept now embraced) emerged, and with it came an unsettling of disciplinary boundaries. Dansgaard, a professor at the University of Copenhagen and a key figure at Camp Century, used his expertise in ice core drilling to assert himself as an expert in fields well beyond his own in geophysics.

By replacing Ahlmann's horizontal outlook with a vertical one, Dansgaard and his colleagues apprehended a radically different cryosphere: A richly textured history became visible through the layers in the ice cores. Ice appeared as a proxy for thousands of years of accumulated data rather than a research object in itself, a 'cold species' that should be monitored in real time. This turn, from horizontal to vertical and from research object to proxy, altered the qualities of ice, transforming it into an environmental object of a different kind, interesting not just in itself but because of the deep time it rendered visible (Carey 2010; Chu 2015, 2020). Ice as proxy, rather than ice as an empirical object in itself, enabled it to move beyond the cryosphere (Isberg and Paglia forthcoming) and become part of larger planetary dynamics, thereby also broadening the scope of what kind of knowledge could be produced by studying it. "The scope of ice core studies reaches far beyond glaciology itself," as Dansgaard himself put it, mentioning climatology, meteorology, geology, and solar physics as possible disciplines with which ice cores could engage (Dansgaard et al. 1973, 5).

Dansgaard's publications after 1966 indicate that the jump in temporal scales also allowed for jumps between disciplines, including as far afield as archaeology and history. In a 1975 article in *Nature*, Dansgaard set out to explain the fifteenth-century demise of a Norse settlement on Greenland by using ice core data to track climatic changes, thereby venturing into the field of historical geography. He went on to connect the fall of the medieval settlement—a proto-Anthropocene event in itself—with contemporary environmental problems on a planetary scale (Dansgaard et al. 1975). The temporal expansion rendered possible through ice core drilling enabled a temporal compression as well, in which the fifteenth century and contemporary politics appeared connected across time by the similarities in environmental degradation. Through the ice cores, Dansgaard emerged as a versatile expert who could make such connections visible. The future also became a domain of his expertise, and Dansgaard developed a preoccupation with projecting climate futures through his "frozen annals" (Dansgaard 2005; see also Dansgaard et al. 1972), as he called them.

In the evolution of a proto-Anthropocene understanding of the relations between historical time and geochronology, Dansgaard's publications in the early 1970s show how they were growing increasingly entangled. The new vertical spatiality of the cryosphere made visible vastly longer timescales, enabling connections between local environments, glaciers, and the dynamics of the entire planet (Figure 2). If Ahlmann was standing on the threshold of a proto-Anthropocene understanding, Dansgaard entered in, albeit without conceptualizing it in this manner and, as his jumps between scales and fields indicate, productively using the lack of a strict disciplinary framework within which to operate.

Another shift that gradually appeared with the emergence of ice as a new kind of environmental object was the geography of the fieldwork itself. The ice cores were no longer bound to local scientific work in the "field cryosphere"; they could be recovered and circulated in a larger scientific infrastructure of ice core repositories that began coming online in Europe and the United States. They became a *portable cryosphere*. Even though ice core drilling still involved a great deal of fieldwork (O'Reilly 2016), much of the scientific work on ice and environmental change could now be conducted in laboratories far away from the site at which the ice originated. Not only the environmental object had changed but its geographical boundaries had changed as well.

After 1966, ice core drilling evolved from being a fairly marginal scientific activity to expand its scope into several scientific disciplines and increasingly into the environmental debate and attempts to project future trajectories of the planet's climate (Carey and Antonello 2017; Elzinga 2017). The ice core brought the glaciers with it to new epistemic geographies of climate knowledge (Mahony and Hulme 2018), altering both the environmental object itself

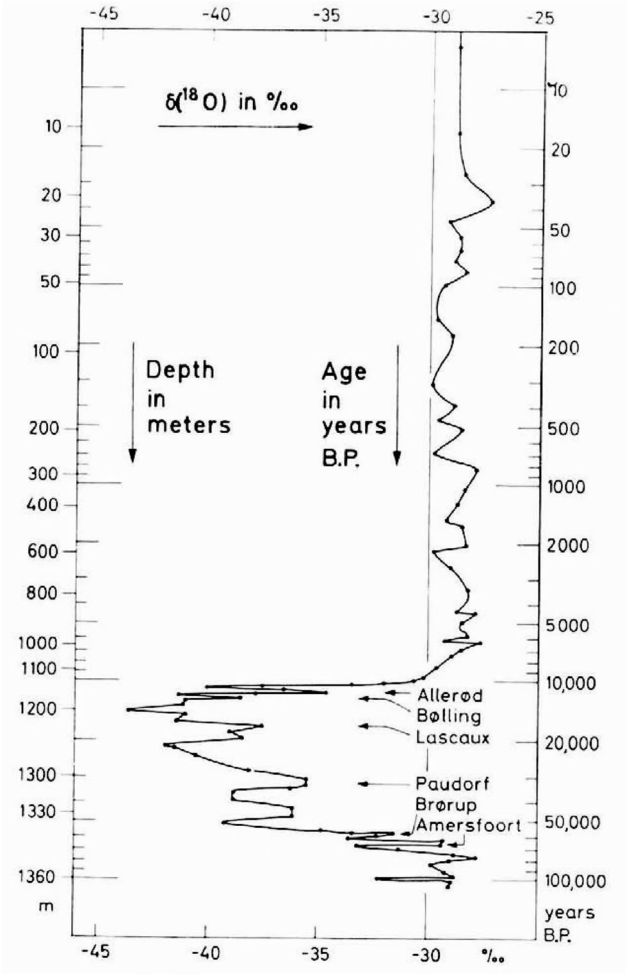

Figure 2. Representation of the 1966 Camp Century ice core with a 100,000-year timescale. *Source:* Dansgaard and Johnsen (1969, 221) (Published with permission by International Glaciological Society, Cambridge, UK.).

and the manner in which to study it. Ice became an environmental object that could be translated into quantifiable data through large-scale computerized climate modeling (Heymann, Gramelsberger, and Mahony 2017), enabling it to move from a remote, singular existence in the cryosphere into a data point in the bourgeoning understanding of an interconnected earth system.

Seeing Scales in Seeds

By the middle of the 1970s, ice core data began to appear in scientific work beyond glaciology in fields such as climatology and oceanography (e.g., Broecker 1975). Rather than watching glacier ice transforming in real time like Ahlmann, or drilling into the ice to uncover the past of a piece of Arctic geography as Dansgaard did, the scientific object that now appeared was ice in a quantified and universalized form. As such, it was something that could operate not just in a North Atlantic context but on a planetary scale. Ice cores, along with other climate proxies such as deep-sea cores, corals, and tree rings, became objects of the earth system, rather than of the geographies from which they were retrieved. They appeared as a new kind of environmental object that could function as proxies for environmental changes well beyond the materiality and location of the objects themselves. In early Earth system science (ESS), these material time records functioned as "archives" that could underpin projections and calculations of the Earth system and were completely detached from the local environments that enabled their appearance in the first place (e.g., Oeschger 1985; NASA Earth System Sciences Committee 1986). With this increasing detachment from the field, concerns were also raised regarding the reductionist dangers in the ESS approach. What were the real-time relationships between aggregated as well as despatialized chronologies and the rates of change and related risks on local or regional levels? The negotiation between different spatial and temporal scales and the materialities that rendered them visible was itself a process unfolding over time.

A case in which this process can be seen is palynology. The study of pollen, spores, and microscopic planktonic organisms began as a scientific field in the early 1900s through the work of the Swedish scientist von Post but later expanded to the United States, and in the 1970s became increasingly enmeshed within the emerging ESS field (von Post 1916; Nordlund 2014; Birks and Berglund 2018; Edwards 2018). Despite the differences in their respective objects of study, ice and pollen, ice core drilling and palynology shared early institutional formation, particularly in a Scandinavian context. In 1951, Dansgaard, together with colleagues at the University of Copenhagen, among them the prominent palynologist Iversen, attended the first "isotope colloquium," in which interdisciplinary approaches to dating methods and the establishment of a special dating laboratory was discussed (Lolck 2004).

It was, to put it differently, a colloquium for different earthly timescales, which shared some key features—being able to interpret through isotope analysis, stratification, and sedimentation—but also differed in some key ways: temporal scope, level of detail, local variabilities, and spatial distribution. Both Dansgaard and Iversen were interested in

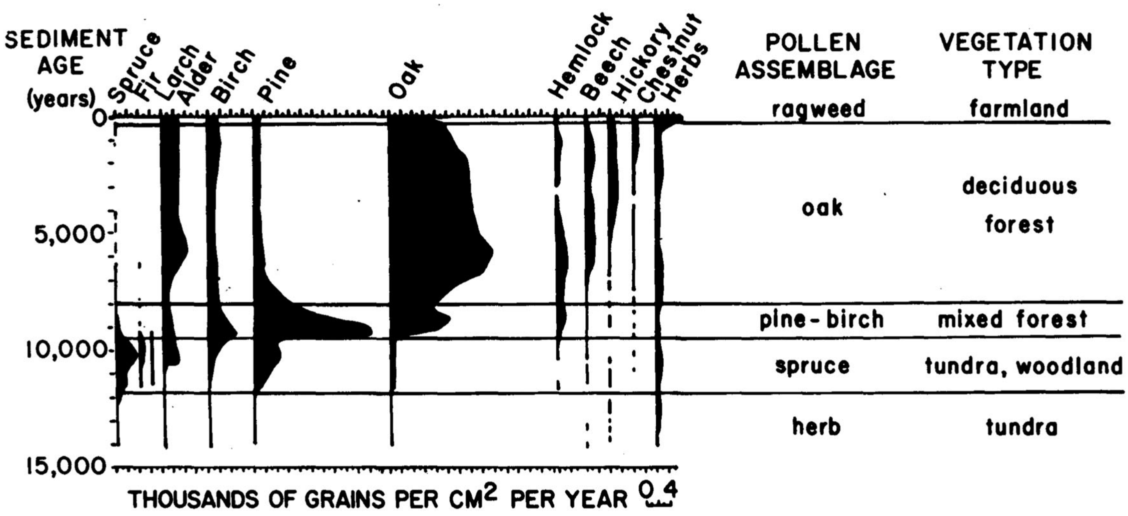

Figure 3. Pollen diagram from southern England with a 15,000-year timescale. *Source:* Davis (1969, 325) (Published with permission by American Scientist.).

climates and environments of the past, but the different materialities and technologies of their respective fields rendered results and representations of historical change that appeared in different ways (Iversen 1953; Dansgaard and Johnsen 1969). The shared institutional framework, yet separate methodologies and results, of Iversen and Dansgaard can serve as an indicative example of the multiple timescales that have coexisted in the making of a synchronized earth system. Particularly the practice of coring, which allowed for analysis of sedimentation and vertical temporal divisions, was common in both fields and rendered it possible to find common ground despite disparate materialities, timescales, and geographies (Figures 2 and 3). Their work, however, also illustrates the nonsynchronicities and the difficulties in reconciling local differences with an all-encompassing idea of the planet as an integrated entity and with the latter becoming an environmental object in its own right.

Three years after the "isotope colloquium," a young Davis, then a Harvard graduate student, went to Copenhagen to study under Iversen and work with the interglacial pollen spectra in western Greenland (Davis 1954). She would later become the head of the Department of Ecology and Behavioral Biology at the University of Minnesota and a leading figure in palynology. Rather than researching the ice sheet itself, which Dansgaard began sampling in the early 1950s, Davis was preoccupied with studying the remains of vegetation that were stored in Greenland's soil and ice. Even though their work in Greenland shared many similarities, and occurred in parallel, their respective approaches to generalization and large-scale modeling came to differ over time. In this way, Davis can serve as an example of the "individualistic response" approach to oversimplified models that threatened to obscure local variation.

From the 1980s, she became increasingly concerned with human environmental impact, particularly emphasizing the relationship between local environments and global climatic changes (Davis 1986a, 1986b). The complex dynamics of local or regional vegetation histories did not self-evidently translate into the models of Earth systems scientists, however (Figure 3). In a 1989 presidential address to the Ecological Society of America, she displayed a cautious stance toward the shifting biome approach visible in generalized models: "This result from the past means that species can be expected to respond individualistically to climatic changes in the future. We must not build models that predict the future by shifting existing communities or biomes around on the surface of the globe" (Davis 1989, 222).

The following year she reiterated the same point, explicitly addressing the International Geosphere-Biosphere Program, and cautioned against oversimplifying ecological processes. Asserting that "the paleorecord argues against such simplification" (Davis 1990, 269), she highlighted a tension between scale jumping and the need to ground scale practices in material and situated environments. Similar concern was voiced by glaciologists working in the Ahlmann–Seligman gradualist tradition, assembling local data that did not fit the modeled reality (Sörlin 2018).

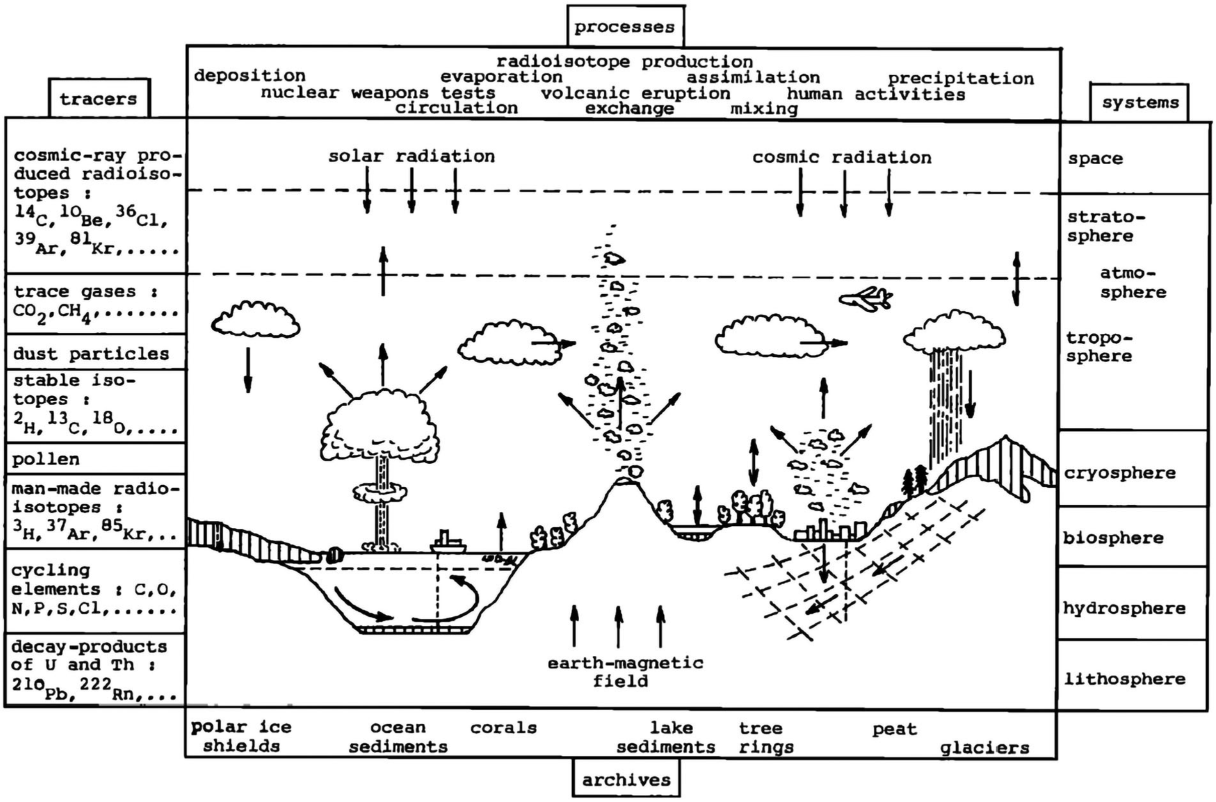

Figure 4. Diagram of the environmental system concept with multiple stylized temporal dimensions. *Source:* Oeschger (1985) (Published with permission by the American Geophysical Union.).

This does not suggest that Davis wanted to distance herself from the integrative ambitions of the early ESS. Rather, their difference in outlook could be understood as a difference in emphasis linked to historically developed materialities and practices. ESS favored big data and large spatial scales, which facilitated synchronizing across timescales. The geographical approaches (gradualist glaciology, case-based palynology), rooted in the field and in comparative data sets and real-time observation over shorter time spans, tended, on the contrary, to produce skepticism toward both large scales and cross-field synchronization. Thus, contemporary critique of the reductionist tendencies of the Anthropocene concept (e.g., Haraway 2015; Yusoff 2019) can be seen in the light of a longer epistemological split, which dates back to the scientific practices that underpin the concept itself.

In the depiction of the 1910 surface extension of Storglaciären in northern Sweden (Figure 1), the *horizontal way of temporalizing* the glacier produced a "landscape of recorded change" (Sörlin 2018, 257) that traced environmental change in real time as a shrinking local area of ice subject to natural climate variability. Photographic documentation, maps, and mass balance measurements made annually were spatially limited to the boundaries of the body of the glacier. The *vertical temporalization* visible in ice core drilling (Figure 2) created a spatially and temporally *different environmental object*: The timescale is vastly increased and the spatial dimensions are not limited to a single glacier or local environment but comparable with timescales from other environmental objects, such as pollen. Palynology, here exemplified by the work of Davis (Figure 3), shares some similarities with the ice core diagram—vertical temporality and a vast timescale—but is also geographically bounded (to New England in this case) and accounts for other environmental factors such as biodiversity. These differences are, however, not visible in the 1985 illustration of the Earth system (Figure 4). Here, different paleochronologies are put under the headline "archives" and are visualized as seemingly unified entities into a larger planetary "environmental system concept." The diagram marks an integration of human agency and politics with geological phenomena—nuclear weapons tests and volcanic eruptions are presented as similar kinds of events—and the synchronized archives are used to underpin this understanding, characteristic of the proto-Anthropocene.

Grounding Earthly Times: Concluding Discussion

Through empirical study of research practices in physical geography and cognate fields, we have tried to demonstrate that the emergence of the Anthropocene can be usefully understood as the result of a longer history of production of integrative human–geological timescales. This work of synchronization, taking place in the second half of the twentieth century, occurred within a broader process of configuring planetary knowledge that would later crystallize in the concept of the Anthropocene. The new approach to geo-chronologies differed fundamentally from earlier understandings when both dating techniques and Quaternary time layers were detached from human agency on large geographical scales. This process of configuration was not the outcome of abstract, intellectual work but rather a product of material and situated scientific practice. When the elements of study, such as ice and pollen, were researched with new methods from neighboring fields (field jumping) and thereby provided new sets of data, scale jumping became possible and eventually resulted in a planetary-scale environmental object with its own embedded temporality.

What can explain the rapid decline of the detached temporalizations of the Earth and human history and the equally swift ascent of a human-agential regime linked to geological timescales? There was obviously nothing wrong with the field data of glaciology, nor with previous data in Arctic plants. Using the North Atlantic as a lens, we have been able to identify distinct moments where new temporal understandings of established elements of study (ice and pollen) emerged at about the same time in the 1950s. Our story, admittedly brief and stylized, suggests that integrative combinations of knowledge were essential in making scale jumping possible, which in turn was necessary to quantify and assess anthropogenic impacts on the global scale.

Further impetus was provided by intellectual forerunners, some of them transformed fieldworkers in possession of strong environmental objects, like Dansgaard. Others were more full-fledged sedentary "meta-specialists" (Warde, Robin, and Sörlin 2018, 63), like oceanographer Broecker, who played a key role in allowing ice core data to travel from their local Arctic confines to become temporal objects with implications for multiple properties of the Earth system (Broecker 1975). In this latter lineage, we can place Crutzen himself, who in 2000 first articulated the Anthropocene concept in its modern form (Steffen, McNeill, and Crutzen 2007). The conceptual innovation marks the beginning of a period of organized scholarly, cultural, and political thinking around the idea of the Anthropocene. Apart from the concept itself, however, very little differentiates Crutzen from his North Atlantic postwar forerunners; he was a product of long-standing work in scaling and synchronizing.

It is therefore useful to identify a proto-Anthropocene understanding beginning before the institutionalization of ESS and the emergence of the Anthropocene concept. This period, largely coinciding with the Great Acceleration since approximately 1950, speaks to the strengths and weaknesses of, respectively, scientific disciplines and the work in those integrative research fields we have discussed here. The proto-Anthropocene phase highlights how the appearance of standardized planetary temporalities, visible in ESS, was the outcome of elaborate work of synchronization and processes of standardizing a multiplicity of proxy records into unified ideas about human–geological timescales. Thus, contemporary debates on the reductionist, and possibly obscuring, tendencies of the Anthropocene should also be seen in light of a longer history of negotiating local variabilities with aggregated, planetary-scale temporalizations.

The production of integrative timescales, and the scientific work that enabled their appearance, speaks to larger questions regarding the ways in which planetary knowledge was produced (Figure 4). The challenge was the combination of vertical and horizontal geographies with the synchronization work that could allow enough explanatory power to human agency. ESS managed to mobilize enough intellectual, institutional, and infrastructural resources to provide the essential building blocks of a new understanding of the human–Earth relationship (Seitzinger et al. 2015). By the mid-1980s, integrative representations of the "environmental system concept" were already in circulation, complete with "tracers" such as pollen, "archives" such as glaciers and peat, "systems" such as cryosphere and biosphere, and "processes" including human agency (Oeschger 1985). Ice and pollen had eventually become input to computerized modeling of planetary dynamics. The innovations that we have identified as instrumental in reaching the new understanding—scale jumping, portability of data, systems approaches, and synchronized, integrative timescales—were all present in ESS and facilitated the formation of a particular epistemology of the human–Earth relationship. This interdisciplinary framework later surfaced as the Anthropocene concept, about a half-century after important work on timescales took place in the North Atlantic region.

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