Hermann Löns' "Quintär" – an early approach to the geological stratigraphy of the Age of Humans and its significance in geosciences

Jahn Jochen Hornung[1]

Abstract: In 1908, Hermann Löns outlined the concept of a "Quintär" ("Quintary period") to describe geological and biological manifestations of the Age of Humans. His definition of the "Quintary" consisted of two components: a lithostratigraphical ("Quintary deposits" or "Quintary stratum"), and a faunistic ("Quintary fauna") one. With a view on the stratigraphical component, Löns already anticipated the approach of the 21st Century to establish a geological definition for the Age of Humans based on physical manifestations and geological evidence, that is nowadays reflected in the attempts to define the anthropocene. Transposed into modern terminology, the "Quintary stratum" is defined as a lithostratigraphical unit (Quintary Lithosome), that contains all deposits in which non-anthropogenic sedimentary processes have been replaced or modified by anthropogenic or technogenic activity. The Quintary Lithosome has a diachronous base and intercalates in its lower part vertically and laterally with non-anthropogenic deposits of the Holocene Series. The upper part, that correlates with the anthropocene series, has a global distribution. The Quintary Lithosome is exclusively

1 *Niedersächsisches Landesmuseum Hannover, Willy-Brandt-Allee 5, 30169 Hannover, jahn.hornung@yahoo.de*

defined for geological stratigraphies on Earth. It widely – though not totally – overlaps with the archaeosphere as a partial equivalent in archaeological stratigraphy. Previous suggestions to redefine the most recent period of Earth history by adopting a biostratigraphical scheme based on hominids and their cultural manifestations, are rejected herein for the realm of geological stratigraphy. However, for the context of archaeological stratigraphy, it is suggested to define the phase of cultural manifestations of hominins and their corresponding deposits as the Anthropian age and deposits, respectively.

Key Words: Quintär; Quintary; Quaternary; Lithostratigraphy; Anthropocene; Age of Humans

INTRODUCTION

Dating back to the middle of the 19th century CE (Common Era), various attempts have been undertaken to characterize and define the current age of Earth's history in which humans became a dominant species as geological unit or era of time in a broader sense (e.g. Crutzen, 2002; Steffen *et al.*, 2011). Recognizing the variety of approaches to this topic, the term "Age of Humans" (e.g. Kress and Stine, 2017) is used herein summarily and independently from the underlying definition or philosophical concept. This term is not to be confused with the calendric Human Era (Emiliani, 1993, 1994).

Roots of the idea for an Age of Humans date back to the late 18th century, mainly in the context of defining a last, concluding stage in the history of Earth that is adorned by the "creation of man", and his perceived exceptional place in nature (see below). The Italian geologist A. Stoppani (1873) is widely credited to have been the first to outline an extensive stratigraphic concept of an "Anthropozoic" based on these premises (Lewis and Maslin, 2015; Grinevald *et al.*, 2019; Rull, 2021), an idea that remained largely obscure for more than a century onwards. Other suggestions during the 20th century – e.g. by P. Teilhard de Chardin and V. Vernadsky – focussed more on holistic, philosophical, or ecological approaches to the matter, rather than to a physical identification of the Age of Humans in the stratigraphic record (e.g. Steffen *et al.*, 2011; Lewis and Maslin, 2015). The latter idea was revived by the suggestion to define a new, most recent geological epoch – the anthropocene[2] - based upon the geological record of the massive influence of human activity on the geo- and biosphere (Crutzen and Stoermer, 2000; Crutzen 2002). This suggestion resulted in the formation of the Anthropocene Working Group of the International Commission on Stratigraphy (ICS, Subcommission on Quaternary Stratigraphy) that is currently outlining the formal definition of the anthropocene as an epoch on the International Stratigraphic Chart (e.g. Zalasiewicz *et al.*, 2008, 2017, 2019a; Waters *et al.*, 2014). These suggestions have found a wide interest in the media and public.

However, despite some historical reviews of the history of the concept (e.g. Steffen *et al.*, 2011; Grinevald *et al.*, 2019) the interesting historical contribution by the German journalist, poet, and amateur naturalist Hermann Löns (1866-1914) to this matter has been overseen until now. Löns developed another suggestion for a new

2 Until the formalization of the anthropocene as a geochronological unit, it will be written herein without a capital letter.

geological age defined by human interaction with the nature that he named “Quintär” (“Quintary”), in allusion to the supposedly preceding Quaternary (Löns, 1908, 1910). While his ideas did not gain momentum and were largely forgotten in the aftermath, they complement the history of the Age of Humans as a term and concept. Furthermore, it reveals a surprisingly progressive early 20th century view on several – yet only partly resolved – issues in the definition of the Age of Humans that found recently a revived interest and urgency. Finally, parts of his concept can be utilized to resolve various of these issues.

THE AUTHOR

Herman Löns (Fig. 1) was born 29 August 1866 in Culm (Western Prussia, today Chełmo, Poland). After he was forced to abandon a study of medicine and natural sciences due to financial constrains, he started to work as a journalist, and finally settled in the area of Hannover, Lower Saxony, in 1892. There he found his passion for the local landscape of the heath (Heide) and became highly popular as author of many essays, poems and books, romanticizing the beauty and appeal of this region, its nature and inhabitants. He volunteered for the German Imperial Army with outbreak of World War I, and was killed in action near Loivre, France, on 26 September 1914 (for extensive modern biographies and receptions see Dupke, 1993, and Kaune, 2014).

Aside of belletristic, popular and educational texts about nature and wildlife (e.g. Wolterstorff, 1938), he published various articles on zoological subjects in local scientific journals. He planned to publish an extensive faunistic study of the

FIGURE 1:
Hermann Löns (1866-1914). Photography taken around 1900, in Public Domain.

vertebrates of southern Lower Saxony. Unfortunately, only early fragments of this

FIGURE 1: Hermann Löns (1866-1914). Photography taken around 1900, in Public Domain.

work became published (Löns, 1905), as he destroyed the manuscript shortly before completion in 1909 (Kaune, 2014). Nonetheless, obviously as an outcome of these faunistic studies, that include the collection of extensive data on neozoans and hemerophiles, as well as historical local extirpation patterns, he developed the concept of the "Quintär" ("Quintary")[3] and the "Quintärfauna" ("Quintary fauna") (Löns, 1908, 1910).

3 For the sake of readability, the English translations of the original terms will be used throughout the text whenever applicable.

THE CONCEPT

Although Löns published his outline as a “zoogeographical suggestion” in the subtitle, he introduced simultaneously two new concepts, the “Quintary” as a stratigraphic term into geosciences, and the “Quintary fauna” into zoology.

The “Quintary”

> “[Ich] nenne [...] diese vom Menschen geschaffene Erdschicht das Quintär als jüngste, dem Alluvium oder Quartär folgende Schicht. Selbstverständlich gibt es Quintär, das bedeutend älter ist als dieses oder jenes Quartär, denn manche kultivierte Gegenden sind als solche älter als die in ihnen liegenden Moor- und Marschbildungen; im allgemeinen ist aber das Quintär geologisch die jüngste Erdschicht, denn erst nachdem die Quartärbildung begonnen hatte, schuf der Mensch das Quintär.
>
> […]
>
> Unter dem Quintär verstehe ich jenen Teil der Erdrinde, dem der Mensch unmittelbar oder mittelbar den Urlandscharakter nahm, also jedes Stück Land, auf dem ein Haus steht, oder das als Straße, Acker, Wiese, Weide, Garten, Park, Anlage, Kirchhof, Deich, Steinbruch usw. durch den Menschen sein von der Urform abweichendes Aussehen erhielt. Diese Umformung bedeutet vom geologischen Standpunkte aus die Schaffung von kleineren und größeren künstlichen Felspartien oder ganzen

Gebirgen durch den Menschen, denn jedes Steinhaus ist ein Fels, jedes Dorf eine Felsgruppe, und jede Stadt ein Gebirge, das viele Schluchten, nämlich die Straßen hat."

"[I call] that man-made stratum, as youngest one, following above the alluvium or the Quaternary, the Quintary. Of course there exists Quintary that is significantly older than this or that Quaternary, because some cultivated regions are older than swamps and marshes located within them; but in general the Quintary is the youngest stratum, because man created the Quintary only after the beginning of the Quaternary.

[…]

As Quintary I define that part of the Earth's crust which was changed directly or indirectly from the ancestral state by man, i.e. every piece of land on which locates a house, or the appearance of which was changed from the ancestral state by humans to a street, field, green, pasture, garden, park, installation, church yard, dike, quarry etc.

From the perspective of geology, this transformation means the creation of smaller or larger, artificial rocky outcrop or whole mountain ranges by man, because every house built from stone is a rock, every village a group of rocks, and every city is a mountain range with many gorges, the streets." (Löns, 1908, pp. 117-118, translated from German by the author).

These quotations imply that – in modern terminology – Löns perceived the "Quintary" as

1 a lithostratigraphic unit, that is composed by *sediments created or modified* by humans, and
2 the *geomorphology* exhibited by this unit, that resulted from human activity.

There is no indication that he intended the "Quintary" as a geochronological unit, but it is explicitly defined as an "Erdschicht" ("geological stratum"), a physical manifestation of (anthropogenic) sedimentary processes. He gave the following diagnostic characteristics of this stratum: It is created by human activity, and includes anthropogenically modified natural deposits (e.g. soils that have been modified by agriculture), as well as those directly created by humans (buildings etc.). Later authors summarized such types of deposits and processes under the term "technogenic" (e.g. Fersman, 1934; Ter-Stepanian, 1988). By remarking that it can be vertically intercalated with deposits that have not been modified by humans (e.g. former agricultural areas that became subsequently wetlands by natural processes) generally overlies the Quaternary, he recognized the "Quintary" deposits as a lithofacies with discontinuous vertical and lateral distribution. He felt some ambiguity to his previous notion, that the "Quintary" in general is the youngest period, a conflict that can be explained by his lack of clear separation of geochronological-chronostratigraphical and lithostratigraphical approaches. However, these can clearly be distinguished by exegesis from his text, and

underscore the identification of the “Quintary deposits” as a *lithostratigraphical* concept.

The “Quintary fauna”

It becomes apparent from the context, that the “Quintary” in a stratigraphic sense was rather a tool for Löns to manifest the temporal element in his zoogeographical theory than a concept on its own rights. The “Quintary” as geological body was understood by him as a man-made substratum that controlled the extant distribution of fauna and flora. The “Quintary fauna” includes species that can only thrive in a certain region, after human activity created a “Quintary deposit”, i.e. the natural landscape has been transformed anthropogenically in a way that new habitat niches were created. He explicitly distinguished his concept from that of neobiota (or neozoans) because the latter he regarded as immigrants that established themselves independently from human landscape modifications (though not necessarily from human activities, as e.g. deliberate introduction of species). He also explained that the “Quintary fauna” is not synonymous to domesticated species, especially as the latter in some cases thrive on “ancestral land”.

The “Quintary fauna” is a zoogeographical context, that was partially defined by a historical and ecological component – the distribution of animal species in time and space depending on their relationship to anthropogenically modified landscapes. Novel in this approach was that the “Quintary fauna” is not equal to species communities that have been wilfully introduced or modified by humans (as e.g.

mentioned in Stoppani, 1873), but those that are able to expand their zoogeographic range and/or abundance because of environmental changes that have been induced by human activity. Examples of these include changes in vegetation patterns due to agriculture, that favoured some mammal and bird biocoenoses (Kalela, 1942); or the provision of warm, sheltered environments in buildings, that allowed for the geographical expansion e.g. of some bat species into northern latitudes (Löns, 1908). The main problem with the "Quintary fauna" is that there is a lack of sufficient empirical evidence in the vast majority of species to clarify the relationship between their local ecological dominance and anthropogenic influence, especially through time. This problem was not ignored by Löns, who admitted a high degree of uncertainty in his categorisation of animal species with regard to their classification as members of the "Quintary fauna".

In modern zoological terminology, "synanthropic fauna" (e.g. Klegarth, 2017) is used largely in an overlapping sense to the "Quintary fauna". This expression has the advantage that it is free from the latter's hypothetical inferences about the causes and chronology of historical faunal changes.

DOES LÖNS' "QUINTARY" HAS CONCEPTUAL PRECURSORS?

Löns did not quote any sources or references in his brief paper about the "Quintary". It therefore remains uncertain from which precursory works his geological and biological conceptions may have been influenced. In order to understand the contemporaneous background of his ideas, important conceptions for stratigraphic

approaches to the Age of Humans until the beginning of the 20th century are summarized chronologically below.

The earliest definition of an Age of Humans as a part of Earth history traces back to Georges-Louis L. de Buffon, who first introduced a “dernière èpoque” (“latest epoch”) that was characterised by the admixture of the “puissance de l’Homme” (“power of man”) to the “power of nature” (de Buffon, 1779: iii). It was significant for being one of the earliest formulations of the idea that a very long period without the presence of humans preceded this “last epoch” (Heringman, 2016).

In the realm of stratigraphy (i.e. the manifestation of diagnostic sedimentary deposits), the earliest attempt to define the Age of Humans can be credited to Henri Reboul (1833: 2). He suggested the terms “periode nèomastonienne” and “periode anthropéienne” as synonyms for the Quaternary, that was recently defined as a stratigraphical unit by Desnoyers (1829; based on Arduino, 1760; see Gibbard, 2019). The “periode nèomastonienne” was based on the appearance of “nouveaux mammifères” and other “quadrumanes” (i.e. extant tetrapods), the “periode anthropéienne” by the presence of humans. Reboul did not suggest a preference for any of these terms, but deliberately suggested them as alternatives. While – in a modern sense – the “periode nèomastonienne” was rooted in a biostratigraphic concept, the proposal of an alternate “periode anthropéienne” included artifacts as potential indicators (“débris osseux ou les produits de quelque industrie grossière” – Reboul, 1833: 5). Most notably, Reboul did not invoke a distinct theological element in his reasoning, in fact, he rejected contemporaneous attempts to utilise geological evidence to prove the historical accuracy of the bible (e.g. the universal deluge). Although he could not explain the “apparition” of new species, he

explained faunal and floral changes as well as extinctions throughout Earth's history as a result of natural, gradual, and regional transformations of the environment (especially of the climate). Anyhow, he underscored the outstanding position of man as "master of the Universe" through its intelligence (Reboul, 1833: 218). Alexandre Vézian later suggested an "ére jovienne" ("jovian era", Vézian, 1863, 1865) that was defined to commence "with the existence of the man, who, after he appeared in this era, never ceased to inhabit the surface of the globe, and whose domination extended more and more." (Vézian, 1865: 450; translated from French). Despite the different terminology, the (bio-)stratigraphic defnition of the "jovian era" is therefore practically identically to that of Reboul's "periode anthropéienne".

Other stratigraphic concepts (sensu lato) in the 19th century mostly center around the exceptionalism of the human species in nature, sometimes with a strong theistic component (e.g. Whewell, 1853; Dana, 1863; Haughton, 1865; Stoppani, 1873; LeConte, 1877, 1878). Generally, such approaches, while they often to some degree included the recognition of physical evidence for human presence, lack concrete, stratigraphically applicable definitions. From the middle of the 19th century, the contemporary and historical physical modifications of the geosphere and biosphere by human activity and their potential for stratigraphy became aware (Jenkyn 1854; Suess, 1862; Marsh, 1864, 1874; Fischer, 1916; Sherlock, 1922; Häusler, 1959; 2016; Hohl, 1974)[4]. In a very elaborate chapter Antonio Stoppani, an Italian geologist and priest, tried to synthesize physical evidence with theological exceptionalism to define an "èra anthropozoica" (Stoppani, 1873), that is often quoted as an early

4 The interaction and interdependencies between human activities and geology became known as „*Anthropogeologie*" („*anthropogeology*") in publications in the German language (see Häusler, 2016 for a historical overview).

precursor of the modern Anthropocene concept (e.g. Crutzen, 2002; Rull, 2021; but see Hamilton and Grinevald, 2015).

Stoppani gave a comprehensive list of the human influence on the biosphere and geosphere, and his unprecedented modifications to the environment. He defined the “anthropozoic era” as to begin with “the first trace of man”, and by that it is ongoing beyond today for “the number of centuries God is willing to concede to the triumph of intelligence and love” (Stoppani, 1873, translated from Italian in Federighi, 2012). Finally, he gave a list of potential sedimentary deposits, their composition and content to record the “anthropozoic era” geologically. With regard to the fossil content he specified – aside of a modern fauna and flora – human remains and anthropogenic artefacts as indicative. Nevertheless, he saw the geological and ecological manifestations of the human presence as the result of the “creation of man”, as “a new element, a new telluric force” to the “physical world”, instead as an integral part of nature. As a result of divine premeditation, Stoppani’s “anthropozoic” does neither recognize the gradual phylogenetic changes that gave rise to the modern human nor the gradual raise in the technological capability of *Homo sapiens* to shape the face of the Earth. It is therefore deeply rooted in theological views, as it not only denies Darwinism but also ignores to respond to the gradual development of human cultures and technology. The hypothesis of an incipient cosmopolitan occurrence (by “creation”) of the human species was unfounded and totally conjectural already at Stoppani’s time. Furthermore, he dated the beginning of the “anthropozoic” after the “neozoic”, the latter of which was characterised by the glaciations. Therefore he implies that it roughly correlates to our current understanding of the Holocene. However, that humans and their

“traces” (in the form of artefacts) reached far more back into the times of glaciation (i.e. into our Pleistocene) was a well established fact already at Stoppani’s time (e.g. Vézian, 1865). He by himself mentioned “[...]archaeolithic strata, where human relics appear as buried among cut firestones and bones of disappeared animals [...]”. The reasons for these contradictions are elusive from Stoppani’s work but it might emphasize the highly dogmatic and theoretical nature of his concept, that could not fully satisfactorily brought into accordance with physical evidence even at the time when it was conceived.

The only potential conceptual precursor to Löns “Quintary”, that roots strictly in stratigraphic methods and is therefore directly comparable, is a regional stratigraphic scheme that incorporated the presence of human fossil and cultural remains by Napoléon de Mercey (1877, here Fig. 2). He defined a “terrain humain” as a regional lithostratigraphic unit in his study on the Quaternary of the Picardy (northeastern France), that was “characterized by the human” (de Mercey, 1877: 21, translated from French) Most interestingly, de Mercey clearly distinguished between lithostratigraphy and chronostratigraphy:

> “Les terrains ou grands groupes d’etages matériels dans l’espace correspondents eux-mêmes à de grands groupes de temps ou époques.”
>
> “The terrains or large units of material stages in space [i.e. depositional successions] correspond to large units in time, or epochs, respectively.”

– De Mercey (1877: 21).

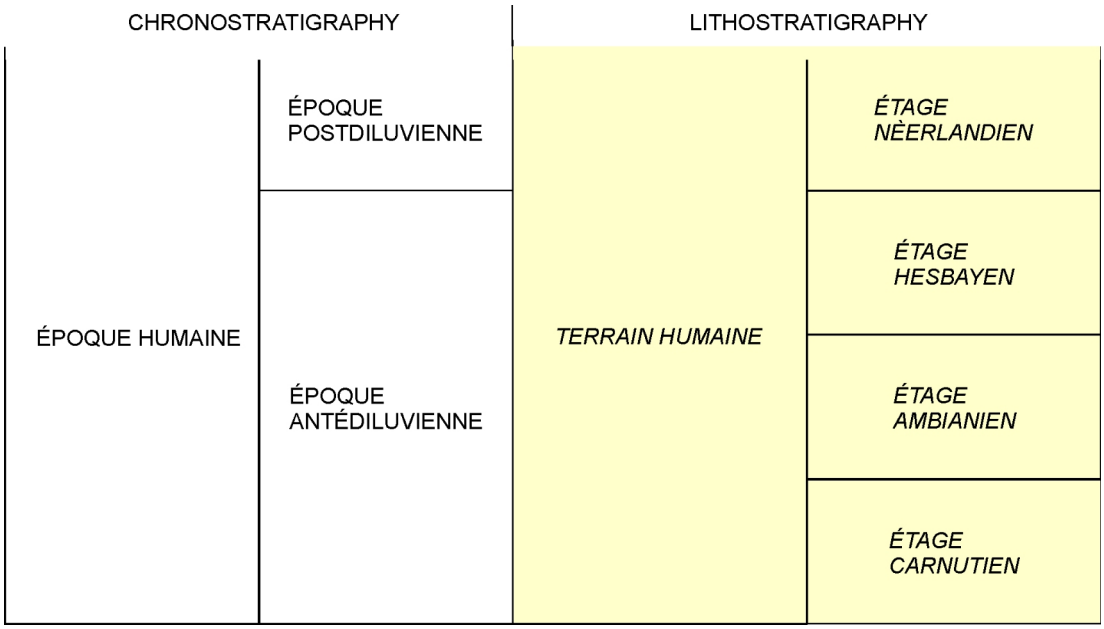

FIGURE 2: The elaborate stratigraphic scheme by de Mercey (1877) for the Quaternary of the Picardy, France. Note the distinction between chrono- and lithostratigraphy, and the usage of the presence of humans as stratigraphic criteria. The boundary between the "époque antédiluvienne" and the "époque postdiluvienne" roughly corresponds to the Weichselian Last Glacial Maximum.

As the chronostratigraphical equivalent to the "terrain humain" he defined the "époque humain". Remarkably, he indicated that human remains and artefacts did not appear at the base of the "terrain humain" but only in the second stage, the "ambianien". De Mercey's stratigraphic system did not prevail, these, only regionally defined, units lack a biostratigraphic definition based on hominids, and their summarily assignment to a "terrain humain" remained theoretical. Similarly, he correlated the "époque humain" to the Quaternary, rendering the former chronostratigraphic unit redundant. His chronostratigraphical concept for further subdivisions of the "époque humain" is vastly outdated (compare e.g. Pillians and Gibbard, 2012).

RECEPTION AND SIGNIFICANCE OF THE "QUINTARY" CONCEPT

Contemporary reception

Neither the "Quintary fauna" nor the "Quintary" made a significant impact on the scientific literature after Löns. The term "Quintärfauna" was rejected first by Boettger (1912: 178), mainly for the – not entirely correct – reasoning that it is synonymous to the term "Adventivfauna". In geosciences the "Quintary" similarly did not got a foothold – the term "Quintär" was only used by a few studies on Quaternary mollusc faunas for the youngest geological units (von Pávai-Vajna, 1911; Vohland, 1914; Petrbok, 1929, 1939). Petrbok (1929: 288) referred to the "Menzel'sche Quintär" as a "historical period" but without a bibliographic reference to his source[5]. The "Quintär" was also mentioned and supported in a study of human-related changes of the Recent avifauna by Kalela (1938, 1942) as "the period of rulership of the humankind [that] is to be seen as a new phase in the development of the organisms" (Kalela, 1942: 2, translated from German).

Aside of these mentions the term cannot be traced further in the primary literature.

Historical significance

As summarized above, definitions for the Age of Humans before Löns were heavily based on theoretical, theological, and philosophical arguments and incorporated only partially empiric methods, if at all. Although Löns' sources of inspiration remain obscure, his concept reflects several ideas that have been formulated before.

5 From the context: probably Menzel (1909).

The “Quintary” in a stratigraphic sense reflects the observations by Reboul (1833), Stoppani (1873), and especially de Mercey (1877) that human remains, artifacts and traces of human activities define a distinct, widespread, and generally uppermost stratum in the geological succession. However, it is novel in defining this stratum as explicitly and exclusively to be that part of the lithosphere which has been modified by human activity, including additions by anthropogenic structures, e.g. buildings.

Löns’ concept stands out for that it did not contain any reference to anthropocentric exceptionalism in nature, as it was rather common in the 19th century. Rather than staying with a vague definition as “the phase of Earth’s history in which humans dominated or existed”, he tried to make the Age of Humans empirically definable by introducing diagnostic geological criteria. Most significantly he explicitly included only those geological strata in his “Quintary” that show clear signs of modification by human activity. By this it became more meaningful, as he puts direct evidence for anthropogenic environmental changes in front for a rationalization of a new phase in the Earth’s history. Not the “appearance” or “creation” of humans – difficult to trace and date – was at the core of his reasoning but the physical documentation of their unprecedented ability to act as a major geological force. Furthermore he recognized the interlude between anthropogenic modifications of the geosphere and consequences for the biosphere – although both terms were not known or understood in his times in a modern sense. The “quintary fauna” reflects the unique consequences that human activities have for global biogeography, an observation that was already adressed by Marsh (1864) and Stoppani (1873).

The suggestion to use empiric indicators of anthropogenic modification of natural sediments as stratigraphical markers is of special significance as it incorporates

environmental factors, similar to modern approaches (Crutzen and Stoermer, 2000; Crutzen, 2002). While it is today a much debated topic which environmental markers may be suitable as characteristic for the Anthropocene (e.g. Crutzen, 2002; Ruddiman, 2013; Steffen *et al.*, 2016; Zalasiewicz *et al.* 2019b), in the early 20th century this suggestion was dismissed, as there were no methods and tools available to analyse these markers sufficiently in the geological record (Menzel, 1909: 90). This problem may have contributed heavily to the negligence of Löns' concept in geosciences.

Löns did not further elaborate on potential geoscientific methods to recognize the anthropogenic influence in sediments. The suggested zoogeographical proxy indicators („Quintary fauna", see below) fall short to solve this problem, as species distribution patterns cannot correlated with human modifications of the environment in sufficient detail in most cases. It also does not allow for a distinction of transitional stages in the evolution of synanthropy. The zoogeographical approach lacks a historical perspective beyond hypotheses to assess the stratigraphic boundaries of the "Quintary".

From a theoretical or philosophical point of view, Löns' approach may be considered unsophisticated or immature. However, explicitly this clear-cut approach – to rely exclusively on physical facts – was undeniable progressive for its time. It reflects modern concepts of human evolutionary exceptionalism in the sense of unique intellectual capabilities (e.g. Simpson, 1949), and their *rebound effects* on the history of life, biological evolution and the Earth System that contrast with the theologically founded assumption that the "appearance" of humans by itself is exceptional in nature. Practically, it anticipated considerations for a stratigraphical

definition of the Age of Humans by evidence from the sedimentary record by nearly 100 years.

DOES THE "QUINTARY" HAS A FUTURE?

The "Quintary", the anthropocene, and the archaeosphere

While various approaches have been proposed for the anthropocene (e.g. Maslin and Lewis, 2015; Barry and Maslin, 2016; Malhi, 2017; Toivanen *et al.*, 2017; Nichols and Gogeneni, 2018; Thober, 2019; Zalasiewicz *et al.*, 2021) it will be focused here on its stratigraphic meaning in the realm of geosciences for a meaningful comparison with the "Quintary".

The anthropocene is aimed to be defined as a chronostratigraphic unit with an isochronous lower boundary, that is defined by global biogeochemical markers in the sedimentary record (Fig. 3). First conceived by Crutzen and Stoermer (2000), the anthropocene was suggested to be defined by the onset of global anthropogenic geochemical markers in the geological record, that give evidence to the profound changes that *Homo sapiens* causes to the Earth System (see also Rull, 2016a). While various suggestions for the type of marker to define the lower boundary have been discussed (e.g. Crutzen, 2002; Ruddiman, 2003; Ruddiman *et al.*, 2020; Gibbard *et al.*, 2021), the Anthropocene Working Group of the ICS currently prefers theanthropogenic radionuclide spike caused by the first nuclear bomb explosion in 1945 CE as boundary marker (e.g. Waters *et al.*, 2014a, b; Zalasiewicz *et al.*, 2014, 2019a; Lewis and Maslin, 2015; Steffen *et al.*, 2015). Its conceptualization follows

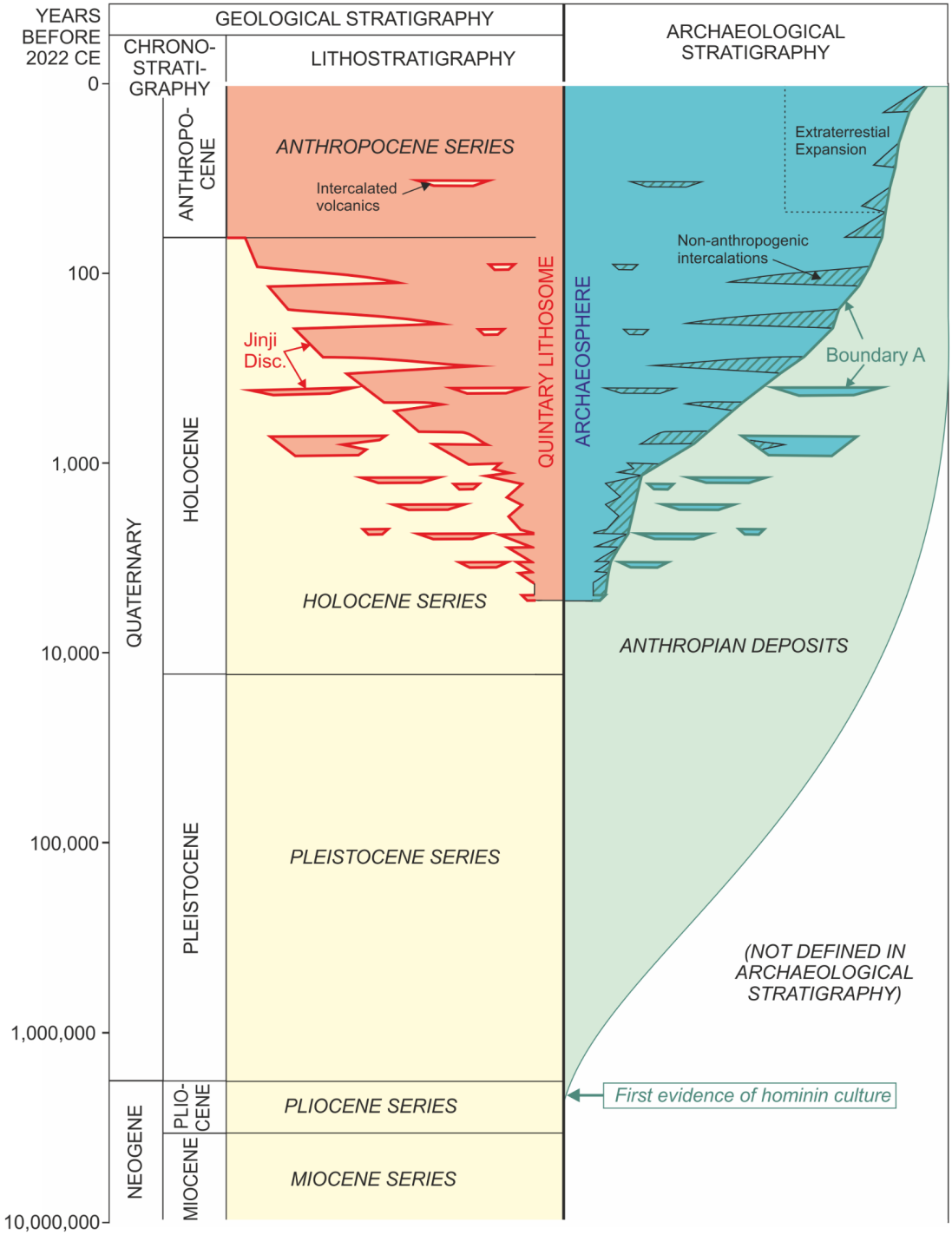

FIGURE 3: Stratigraphy for the Age of Humans as suggested herein for the geological (left, Quintary Lithosome, orange) and archaeological realm (right, archaeosphere: turquoise, Anthropian deposits: green). Intercalated non-anthropogenic deposits in the archaeosphere are indicated by diagonal hatching. See text for further explanations. Base of the anthropocene epoch assumed at 1945 AD, following Zalasiewicz et al. (2019a), other absolute ages after Cohen et al. (2013, updated 2021), note the logarithmic scale.

strictly a stratigraphical approach but is subject to ongoing controversial discussions (e.g. Gale and Hoare, 2012; Hamilton, 2016; Malhi, 2017; Ruddiman, 2018; Rull, 2016a, b, 2021; Nielsen 2021a, b). Most recently, Gibbard *et al.* (2021) proposed to define the anthropocene as a stratigraphic event (sensu Ager, 1973) rather than a formalized epoch, with the aim to better embrace its time-transgressive nature and the wide range of manifestations of the Age of Humans.

To the contrast, the "Quintary" is perceived as a lithostratigraphic, diachronous unit that is neither laterally nor vertically continuous and has no binding to a geochronological unit. By original definition (Löns, 1908), *it comprises all geological strata that have been formed by processes dominated or even created by human activity (implicitly on planet Earth). Recognition of these strata in the geological record depend on the empirical identification of physicochemical markers of human activity.*

Exemplary discussions of such markers can be found e.g. in Ford et al. (2014), Lane et al. (2019), and Mayoral *et al.* (2020). Human activity manifests geologically mostly – though not exclusively – in a broad range of ichnological (trace- or 'work'-related) and physicochemical phenomena (e.g. Zalasiewicz, 2013; Ford *et al.*, 2014; Williams *et al.*, 2014; Goudie and Viles, 2016).

Hamilton and Grinevald (2015) have argued that concepts for the Age of Humans preceeding that of the anthropocene (sensu Crutzen and Stoermer, 2000) should not be considered historical precursors of the latter. This view was rationalised by the radical different approach of the anthropocene as a chronostratigraphic unit, defined by a distinct transition of humanity's capability to transform Earth's surface towards a modification of the Earth System, decoupled from the preceding gradual

evolution of human culture and technology. However, by its connection to the geological products of human activity, and its recognition of the lateral and vertical intercalation of these product with non-anthropogenic strata, the Quintary as a stratigraphic body, also termed more informally the "*human stratum*" (Zalasiewicz, 2008), is an expression of the processes that form the basis for recognition of the anthropocene. It is therefore a complementation rather than a precursory or alternative approach.

The diachrony of anthropogenic or anthropogenically influenced deposits pose a terminological problem with a chronstratigraphic definition of the anthropocene that has been addressed before (e.g. Periman, 2006; Edgeworth *et al*., 2015, 2019; Ruddiman, 2018; Zalasiewicz *et al*., 2019b). The entire succession of anthropogenic deposits has recently been termed summarily the *archaeosphere* (Capelotti, 2009; Edgeworth, 2014). The archaeosphere globally overlies the non-anthropogenic deposits with a basal disconformity, that was named *Jinji disconformity* (Nirei *et al*., 2012) or *Boundary A* (Edgeworth, 2014, 2018; Edgeworth *et al*., 2015). It provides an alternative framework to interpret the geological manifestations of human activities independently from the onset of a global datum. However, a conceptual harmonization of the archaeosphere with the anthropocene is not yet fully achieved. Edgeworth et al. (2015, 2019) proposed a merger of the archaeosphere (as a stratigraphic unit) into the anthropocene and to accept a diachronous base for the latter, contrary to its current intention. Alternatively, they suggested that the archaeosphere may be established in parallel to the anthropocene as a non-chronostratigraphic unit (similar to a biozone).

Both approaches attempt to synchronize two quite different stratigraphies: the geological and the archaeological. This proves to be difficult because a diachronously defined anthropocene would miss the intention of the concept in a similar way as a re-definition of the archaeosphere as a bio- or culture zone. Such a stratigraphic zone needs to be globally definable but its physical manifestations (in the sense of archaeological traces) may not be present everywhere. In the remaining wildernesses of the Earth, global human impact can mostly only be measured by biogeochemical methods (e.g. tracers in sediments and atmospheric gases) rather than in archaeological remnants or textural changes to the sedimentary deposits. Furthermore, the archaeosphere is explicitly defined to extend to outer space, manifesting on non-terrestrial celestial bodies on which humans have left artefacts (Capelotti, 2009), while geological stratigraphic bodies and ages defined on Earth are bound to this planet.

In comparison it becomes clear that the concept of the “Quintary” is very similar to that of the archaeosphere. However, there are two tangible distinctions:

1 in contrast to the “Quintary”, the archaeosphere can contain interlayers devoid of anthropogenic influence (e.g. from natural floods),
2 the “Quintary” was not recognized outside the limit of the terrestrial geosphere (e.g. in interplanetary space or on extraterrestrial bodies).

It has the advantage that it was completely framed within terrestrial geology, and recognizes the diachrony of the onset of this unit, as well as its lateral discontinuous distribution. It therefore recommends itself as a useful term within the framework

of *geological stratigraphy* for deposits created by or physically modified by human activities. The term archaeosphere should therefore be restricted to the usage in the context of *archaeological stratigraphy*. The lower boundary of the archaeosphere is marked by Boundary A as equivalent to the Nirei discontinuity (Fig. 3), a name that was introduced in an archaeological context (Edgeworth, 2014).

The idea to use the presence of human fossil or cultural remains as (bio-)stratigraphic indicators in geological stratigraphy date back to the 19th century (Stoppani, 1873; Pavlov, 1922; Gerasimov, 1979), and was recently revived by Rull (2021). However, the fossil record of hominins is exceedingly sparse, and before the acquaintance of advanced technological abilities their the impact on the Earth System was insignificant. It increased only gradually, and a widespread physical evidence for the presence of humans in the stratigraphic record only coincides with its latest phylogenetic stage from the late Holocene onwards. From the current perspective, a biostratigraphy based on fossil or cultural remains of hominins does not serve a practical purpose in geosciences. Therefore it is also not productive to re-define the Quaternary as “Anthropogene” (Pavlov, 1922), or to create a new “Quintary” or “Quinary Period” (Ter-Stepanian, 1988) succeeding the Quaternary Period for the anthropocene epoch. Similarly, hypothetical future stratigraphic boundaries, as suggested to define a “technogene” following the Holocene (Ter-Stepanian, 1988) are not recommendable in geological stratigraphy.

Nonetheless, human (hominin) culture is much older than its ability to significantly influence geological processes, and several million years of sentient human existence has already passed before the creation of Boundary A and the archaeosphere. It is therefore proposed to define this interval in archaeological

stratigraphy as the phase of cultural expression of hominins, and its lower boundary with the appearance of the oldest anthropogenic artefacts in the stratigraphic record (i.e. the base of the Lower Paleolithic). Currently, the oldest stone implements have been found in Pliocene deposits of Kenya dated to 3.3 ma, and are by this significantly older than the oldest skeletal record of the genus *Homo* (see Harmand *et al.*, 2015). Such an overarching definition for the phase of cultural activity of humans has been anticipated already by Reboul (1833), and it is recommended herein to adopt his term "*periode anthropéienne*" as the *Anthropian*[6]. By definition, the Anthropian spans all periods of hominin prehistory and history up to the present, and into the future for the time of existence of the material human culture. The archaeosphere forms part of the deposits of the Anthropian. Furthermore, the base of the Anthropian deposits is diachronous, according to the dispersion of hominins and their technology across the globe. While it e.g. dates back to the Pliocene in Africa, it is not older then the Late Pleistocene in the Americas, and not older then the latest Holocene (late 19th century CE) in Antarctica.

The Quintary Lithosome

If considered as a lithostratigraphic unit, the "Quintary" deposits are difficult to establish in the formal scheme of hierarchical stratigraphical nomenclature for various reasons. First of all, they are diachronous and partially laterally discontinuous in extent, as well as intertongueing with non-anthropogenic/non-

6 Suggested translations: French: *Anthropéien*, German: *Anthropium*, Italian: *Anthropeano*.

technogenic deposits. Second, anthropogenically/technogenically modified deposits encompass an enormous range of lithofacies, from anthropogenic landscapes (e.g. edifices) to the macroscopically invisible admixture of anthropogenical components (e.g. radionuclides or microplastic particles) in non-anthropogenically formed sediments (e.g. deep sea deposits). The variation of geological bodies that are either formed or influenced by human activity is so broad, that a single, formal lithostratigraphical unit as a formation or a group would be inadequate to characterise them. However, if the anthropocene as a geochronological unit is defined by the global presence of anthropogenic physicochemical tracers in contemporary sedimentary systems, it may be argued that the corresponding anthropocene series is identical to the "Quintary" deposits. Nonetheless, such an approach would not solve the dilemma of the diachronous nature of Holocene anthropogenic deposits. Most ironically, the definition of the "Quintary" succession (1908 CE) would have predated the proposed onset of deposition of the anthropocene series (1945 CE) by nearly half a century. Alternatively, the restriction of the "Quintary" succession to pre-anthropocene anthropogenic deposits would also not be adequate as the majority of anthropogenic processes that creates this succession (e.g. soil modification by agriculture) continues seamlessly from the Holocene into the anthropocene.

A solution to these dilemmas may be the recognition of the Quintary succession as a lithosome. The lithosome as an informal lithostratigraphic unit was suggested first by Wheeler and Mallory (in Fischer *et al.*, 1954, Wheeler and Mallory, 1957) and modified by Sando (1989: E3) to the following definition:

> A vertically and horizontally segregated body of sedimentary rock, characterized by its lithic content and inferred genetic significance, which mutually intertongues with one or more bodies of different lithic constitution. A lithosome may or may not be demonstrably diachronous as measured by iths transgression of time planes based on biozones or physical means of measuring time.

Lithosomes are interdependent in extension from formal lithostratigraphic units although they often coincide with the latter. The age relationships of their vertical boundaries are determined biostratigraphically, geochronologically, or lithostratigraphically, and their lateral boundaries “by regional lithostratigraphic analysis of the total time interval occupied by the lithosome throughout its lateral extent” (Sando, 1989).

By recognizing the “Quintary” succession as the *Quintary Lithosome*, it can be defined by containing components or textures that are linked to human activity as significant genetic factors. It is diachronous, beginning with the oldest anthropogenically modified or created deposits. As a deviation from the current definition of a lithosome it might be perceived that isolated bodies of anthropogenic deposits (e.g. debris around temporary Holocene human settlements) can occur isolated from other anthropogenic deposits (i.e., being underlain, overlain, and/or laterally bounded by non-anthropogenic successions) and therefore be detached from a continuous anthropogenic sedimentary body. However, the definition of a lithosome does not strictly exclude such a configuration. Presuming its unique genetic significance and mode of formation, there is a good reasoning to include

such detached occurrences into the Quintary Lithosome. There is also no objection to the naming, as Löns (1908) alluded to the succession to the Quaternary – while not in a geochronological sense, this is well in accordance to the perception that the Quintary Lithosome was exclusively formed by a "novel agent" in Earth' s history: the humankind. It has also the advantage to be regionally and culturally neutral.

For the lower boundary of the Quintary Lithosome the term Jinji discontinuity is appropriate, as it was introduced in a geological context (Nirei *et al.*, 2012). In yet untouched wilderness areas, the Jinji discontinuity corresponds to the first appearance of geochemical indicators for the anthropocene (i.e. anthropogenic radionuclides) in the sedimentary record. The boundary surface in these regions can be expected to be mostly stratigraphically conformable, hence the proposal to define it as a discontinuity rather than as a disconformity.

While the Quintary Lithosome is largely identical to the archaeosphere on planet Earth in its extent, some differences exist: the pre-anthropocene archaeosphere is corresponding in extent to the Holocene part of the Quintary Lithosome, but it may be – in contrast to the extent of the anthropocene section of the Quintary Lithosome – restricted geographically during the anthropocene to those regions (on Earth and beyond) that underwent intentional modification by humans (e.g. building, excavation, landfills, plowing, etc...). The upper part of the Quintary Lithosome attains global distribution may represent nearly entirely the anthropocene series – it may be a matter of discussion if volcanic effusiva deposited during the anthropocene should be included or not, as they can be considered devoid of anthropogenic components. The anthropocene succession of the Quintary Lithosome is characterized by the global presence of biogeochemical tracers in

sedimentary deposits, demonstrating global influence of human activity on the geological record. As recent studies have shown (Meszar *et al.*, 2021), the boundary between the Holocene and the Anthropocene Series is even recognisable in fully anthropogenic, urban deposits by geochemical tracing.

Finally, a recognition of the Quintary Lithosome would not affected the reclassification of the anthropocene as a stratigraphic event, rather than a geochronological unit, as recently suggested by Gibbard *et al.* (2021).

CONCLUSIONS

In a brief paper, Löns (1908) outlined the concept of a "Quintary period" to describe geological and biological manifestations of the Age of Humans. While his focus was directed on zoogeographical conclusions, his approach to the "Quintary" was twofold: lithostratigraphical ("Quintary deposits" or "Quintary stratum"), and faunistic ("Quintary fauna").

While the zoogeographical meaning of the "Quintary" was impractical to employ in practice, its lithostratigraphical definition is useful and still meaningful within the frame of modern stratigraphical concepts discussed for the Age of Humans. It fills a gap in defining diachronous, anthropogenic or anthropogenically influenced deposits of Holocene to anthropocene age within the framework of chrono- and lithostratigraphy. Therefore, the "Quintary" can have a future, as a term, and as the product of ongoing geological processes in the Earth System. While ahead of its time, especially with a view on the required analytical techniques to provide the

necessary physical evidence – and probably mostly neglected for this reason – today's geological and archaeological techniques allow to fulfill these prerequisites.

With regard to its modern significance, the following conclusions are drawn from a reassessment of Löns' "Quintary":

- The "Quintary" was clearly and validly defined as a lithostratigraphical unit by Löns (1908). In mordern terminology, this unit can be categorized as a lithosome (sensu Sando, 1989). The Quintary Lithosome contains all deposits on planet Earth in which non-anthropogenic (i.e. "natural") sedimentary processes have been replaced or modified by human activity.
- The Quintary Lithosome has a diachronous base (marked by the Jinji discontinuity) and intercalates in its lower part vertically and laterally with non-anthropogenic deposits of the Holocene Series. The upper part forms the majority or even entirety of the anthropocene series, has a global distribution and is characterized by the incorporation of anthropogenic particles and/or geochemical markers (e.g. microplastics, anthropogenic radionuclides, etc.) in anthropogenic as well as non-anthropogenic sedimentary systems.
- The Quintary Lithosome is widely overlapping with the archaeosphere in archaeological stratigraphy., The archaeosphere represents strata that have been formed by significant interruption and replacement of non-anthropogenic by anthropogenic (technogenic) sedimentary processes. In contrast to the Quintary Lithosome, these strata may be intercalated with strata that formed as result of non-anthropogenic sedimentary processes.

While its lower boundary (Boundary A) largely coincides with the Jinji discontinuity, it extends beyond planet Earth through human artefacts that have been brought to outer space. On the other hand it may be geographically more constrained during the anthropocene than the Quintary Lithosome because there are still areas on Earth that did not underwent a significant modification of their natural sedimentary processes through technogenic interference (e.g. wilderness regions). Concurrently, and as a consequence, the archaeosphere is expansive (for the time during which human civilization will be expanding on Earth and beyond), while the Quintary Lithosome has, by definition, already extended to a global distribution during the anthropocene.

- There is no justification to define a subsequent period to the Quaternary for the Recent. The anthropocene epoch (to be formalized as Anthropocene) is rightfully nested within the Quaternary.
- Previous suggestions to redefine the most recent period of Earth history by adopting a biostratigraphical scheme based on hominids and their cultural manifestations, are rejected herein for the realm of geological stratigraphy. Hominid fossils and anthropogenic artefacts are not suitable for reliable or useful biostratigraphic zonation. However, in the context of archaeological stratigraphy it is suggested to define the phase of cultural manifestations of hominins (starting with the Lower Palaeolithic during the Pliocene) as the Anthropian age.

While the above suggestions represent modernized terminologies and adaptations to current conventions, it has to be stressed that these adaptations are minor in comparison to the original concept. It may therefore be stated, that the contribution of Hermann Löns to scientific debates that have significance more than a century later in geosciences, as well as in fields spanning from ecology to philosophy, deserves more attention than it has been historically received.

Contrasting with precursors, Löns already anticipated the approach of the 21st century for definitions based on physical manifestations and geological evidence. His theoretical framework is also free from anthropocentric and theistic components that were dominant in discussions of human exceptionalism in nature during the 19th century. Originally, his geoscientific considerations were merely a supporting framework for his aim of a zoogeographical interpretation of the local fauna. But in their focus on factual description they form a valuable and novel contrast to many precursors, and allow for a nearly seamless integration to modern concepts that likewise aim to base themselves in factual evidence.

REFERENCES

Ager, D.V., 1973. The Nature of the Stratigraphic Record. New York, Wiley, 151pp.

Arduino, G. 1760. Due lettere […] sopra varie sue osservazioni naturali: Al Chiaris. Sig. Cavalier Antonio Vallisnieri professori di Storia Naturale nell'Università di Padova: Lettera Prima […] Sopra varie sue Osservazioni Naturali (Vizenca, 30 gennaio 1759): Lettera Seconda […] Sopra varie sue Osservazioni fatte in diverse parti del Territorio di Vicenza, ed altrove, appartinenti alla Teoria Terrestre, ed alla

Mineralogia (Vizenca, 30 marzo 1759). Nuova Raccolta di Opuscoli Scientifici e Filologici, 6, 99-180.

Barry, A., Maslin, M., 2016. The politics of the anthropocene: a dialogue. Geo: Geography and Environment, 3(2), e00022.

Boettger, C.R., 1912. Die Molluskenfauna der preussischen Rheinprovinz. Archiv für Naturgeschichte, 78A, 149-316.

de Buffon, G.-L.L., 1779. Suppléments à l'Histoire Naturelle, Générale et Particuliére, V, Des Époques de la Nature. Paris, Imprimerie Royale, 258pp.

Capelotti, P.J., 2009. The Human Archaeology of Space: Lunar, Planetary and Interstellar Relics of Exploration. Jefferson, McFarland & Co., 199pp.

Cole, G.A.J., 1923. Man as a Geological Agent: An Account of His Actions on Inanimate Nature [book review]. Nature, 111, 352-354.

Cohen, K.M., Finney, S.C., Gibbard, P.L., Fan, J.-X., 2013 (updated version 2021/07). The ICS International Chronostratigraphic Chart. Episodes, 36, 199-204.

Crutzen, P.J., 2002. Geology of mankind. Nature, 415, 23.

Crutzen, P., Stoermer, E., 2000. The "Anthropocene". Global Change Newsletter, 41, 17-18.

Dana, J.D., 1863. Manual of Geology. Philadelphia, Theodore Bliss & Co., 798pp.

Desnoyers, J., 1829. Obervations sur un ensemble de dépots marins plus récents que les terrains tertiaires du bassin de la Seine, et constituant une formation géologique distincte: précedées d'un apercu de la nonsimultanéité des bassins tertiaires. Annales scientifiques naturelles, 16, 171-214.

Dupke, T., 1993. Mythos Löns. Heimat, Volk und Natur im Werk von Hermann Löns. Wiesbaden, Deutscher Universitätsverlag, 381pp.

Edgeworth, M., 2014. Archaeology of the Anthropocene: introduction. Journal of Contemporary Archaeology, 1, 73-77.

Edgeworth, M., 2018. More than just a record: active ecological effects of archaeological strata. In: Torres de Souza, A., Menezes Costa, D. (eds.). Historical Archaeology and Environment. Cham, Springer, 19-40.

Edgeworth, M., Richter, D. deB., Waters, C., Haff, P., Neal, C., Price, S.J., 2015. Diachronous beginnings of the Anthropocene: The lower bounding surface of anthropogenic deposits. The Anthropocene Review, 2(1), 33-58.

Edgeworth, M., Ellis, E.C., Gibbard, P.L., Neal, C., 2019. The chronostratigraphic method is unsuitable for determining the start of the Anthropocene. Progress in Physical Geography: Earth and Environment, 43(7), 334-344.

Emiliani, C., 1993. Calendar reform. Nature, 366, 716.

Emiliani, C., 1994. Calendar reform for the year 2000. Eos, 75(19), 218.

Federighi, V., 2013. The Anthropozoic Era: Excerpts from Corso di Geologia. Scapegoat, 5, 346-353.

Fersman, A.E., 1934. Geokhimiia. II. Leningrad, ONTI-Khimteoret, 503pp.

Fischer, E., 1916. Der Mensch als geologischer Faktor. Zeitschrift der Deutschen Geologischen Gesellschaft, 67(for 1915), 106-148.

Fischer, A.G., Wheeler, H.E., Mallory, V.S., 1954. Arbitrary cut-off in stratigraphy. Bulletin of the American Association of Petroleum Geologists, 38(5), 926-931.

Ford, J.R., Price, S.J., Cooper, A.H., Waters, C.N., 2014. An assessment of lithostratigraphy for anthropogenic deposits. In: Waters, C.N., Zalasiewicz, J.A., Williams, M., Ellis, M., Snelling, A.M. (eds.). A stratigraphical basis for the Anthropocene. Geological Society, London, Special Publications, 395, 55-89.

Gale, S.J., Hoare, P.G., 2012. The stratigraphic status of the Anthropocene. The Holocene, 22(12), 1491-1494.

Gerasimov, I.P., 1979. Anthropogene and its major problem. Boreas, 8(1), 23-30.

Gibbard, P.L., 2019. Giovanni Arduino – the man who invented the Quaternary. Quaternary International, 500, 11–19.

Gibbard, P.L., Bauer, A.M., Edgeworth, M., Ruddiman, W.F., Gill, J.L., Merritts, D.J., Finney, S.C., Edwards, L.E., Walker, M.J.C., Maslin, M., Ellis, E.C., 2021. A practical solution: the Anthropocene is a geological event, not a formal epoch. Episodes, preprints, https://doi.org/10.18814/epiiugs/2021/021029

Grinevald, J., McNeill, J., Oreskes, N., Steffen, W., Summerhayes, C., Zalasiewicz, J., 2019. History of the Anthropocene concept. In: Zalasiewicz, J., Waters, C.N., Williams, M., Summerhayes, C. (eds). The Anthropocene as a Geological Time Unit: A Guide to Scientific Evidence and Current Debate. Cambridge, Cambridge University Press, 4-11.

Goudie, A.S., Viles, H.A., 2016. Geomorphology in the Anthropocene. Cambridge, Cambridge University Press, 380pp.

Hamilton, C., 2016. The Anthropocene as rupture. The Anthropocene Review, 3(2), 93-106.

Hamilton, C., Grinevald, J., 2015. Was the Anthropocene anticipated? The Anthropocene Review, 2(1), 59-72.

Harmand, S., Lewis, J.E., Feibel, C.E., Lepre, C.J., Prat, S., Lenoble, A., Boës, X., Quinn, R.L., Brenet, M., Arroyo, A., Taylor, N., Clément, S., Daver, G., Brugal, J.-P., Leakey, L., Mortlock, R.A., Wright, J.D., Lokorodi, S., Kirwa, C., Kent, D.K., Roche, H., 2015. 3.3-

million-year old stone tools from Lomekwi 3, West Turkana, Kenya. Nature, 521, 310-315.

Haughton, S., 1865. Manual of Geology. London, Longman, Green, Longman, Roberts & Green, 360pp.

Häusler, H., 1959. Das Wirken des Menschen im geologischen Geschehen. Eine Vorstudie zur Anthropogeologie als allgemeines Ergebnis geologisch-technischer Untersuchungen im Großraum von Linz. Naturkundliches Jahrbuch der Stadt Linz, 1959, 163-319.

Häusler, H., 2016. Die Menschheit als geologischer Faktor: Von der Anthropogeologie zur Umweltgeoforschung im Anthropozän. Berichte der Geologischen Bundesanstalt, 118, 20-65.

Heringman, N., 2016. Buffons Époches de la Nature (1778) und die Tiefenzeit im Anthropozän. Zeitschrift für Kulturwissenschaften, 10(1), 73-85.

Hohl, R., 1974. Anthropogene Endo- and Exodynamik im Territorium, ein neues Grenzgebiet zwischen Geologie, Geographie, Technik und Ökonomie. Zeitschrift für Geologische Wissenschaften, 2(8), 947-961.

Jenkyn, T., 1854. Lessons in Geology, Chapter IV: On the Effects of Organic Agents on the Earth's Crust. Section IV: The Results of the Agency of Man. The Popular Educator, 4, 139-141.

Kalela, O., 1938. Über die regionale Verteilung der Brutvogelfauna im Flussgebiet des Kokemäenjoki. Annales Zoologici Societas Zoologicae-Botanicae Fennicae Vanamo, 5(9), 1-297.

Kalela, O., 1942. Die Ausbreitung der kulturbedingten Vogelfauna als Glied der spätquartären Faunengeschichte Europas. Ornis Fennica, 19(1), 1-23.

Kaune, R., 2014. Lieben, Leben, Leiden. Hermann Löns in Hannover, Schaumburg-Lippe und der Lüneburger Heide. Erfurt, Sutton, 123pp.

Klegarth, A.R., 2017. Synanthropy. In: Fuentes, A. (ed.). The International Encyclopedia of Primatology. Hoboken, John Wiley & Sons, https://doi.org/10.1002/9781119179313.wbprim0448

Kress, J.W., Stine, J.K. (eds), 2017. Living in the Anthropocene: Earth in the Age of Humans. Washington D.C., Smithonian Books, 208pp.

Lane, S.N., Bakker, M., Costa, A., Girardclos, S., Loizeau, J.-L., Molnar, P., Silva, T., Stutenbecker, L., Schlunegger, F., 2019. Making stratigraphy in the Anthropocene: climate change impacts and economic conditions controlling the supply of sediment to Lake Geneva. Scientific Reports, 9(8904), https://doi.org/10.1038/s41598-019-44914-9

LeConte, J., 1877. On critical periods in the history of the Earth and their relation to evolution: and on the Quaternary as such a period. The American Naturalist, 11(9), 540-557.

LeConte, J., 1878. Elements of Geology. New York City, D. Appleton and Company, 588pp.

Lewis, S.L., Maslin, M.A., 2015. Defining the Anthropocene. Nature, 519, 171-180.

Löns, H., 1905. Bitte, die Wirbeltierfauna von Hannover betreffend. Jahresberichte der Naturhistorischen Gesellschaft zu Hannover, 50-54, 247-264.

Löns, H., 1908. Die Quintärfauna von Norddeutschland. Jahresberichte der Naturhistorischen Gesellschaft zu Hannover, 55-57, 117-127.

Löns, H., 1910. Das Quintär und seine Fauna. Kosmos, 7, 447-449.

Malhi, Y., 2017. The concept of the Anthropocene. Annual Review of Environment and Resources, 42, 77-104.

Marsh, G.P., 1864. Man and Nature; or, Physical Geography as Modified by Human Action. New York City, C. Scribner, 560pp.

Marsh, G.P., 1874. The Earth as Modified by Human Action. New York City, Scribner, Armstrong & Co., 656pp.

Maslin, M.A., Lewis, S.L. 2015. Anthropocene, Earth System, geological, philosophical and political paradigm shifts. The Anthropocene Review, 2(2), 108-116.

Mayoral, A., Granai, S., Develle, A.-L., Peiry, J.-L., Miras, Y., Couderc, F., Vernet, G., Berger, J.-F., 2020. Early human impact on soils and hydro-sedimentary systems: Multi-proxy geoarchaeological analyses from La Narse de la Sauvetat (France). The Holocene, 30(2), 1780-1800.

Menzel, H., 1909. Über die Quartärfaunen im nördlichen Vorlande des Harzes und die Nehring'sche Steppenhypothese. Centralblatt für Mineralogie, Geologie und Paläontologie, 1909, 87-94.

de Mercey, N., 1877. Sur la classification de la période Quaternaire en Picardie. Mémoires de la Société Linnéenne du Nord de la France, 4, 18-28.

Meszar, M., Hain, K., Wagreich, M., Lappé, K., Mosser, M., Hornek, K., Koukal, V., Litschauer, C., Piperakis, N., 2021. Tracing the Anthropocene bomb-spike in urban strata of Vienna. EGU General Assembly 2021, 19–30 Apr 2021, EGU21-11930, https://doi.org/10.5194/egusphere-egu21-11930

Nichols, K., Gogeneni, B., 2018. The Anthropocene's dating problem: Insights from the geosciences and the humanities. The Anthropocene Review, 5(2), 107-119.

Nielsen, R.W., 2021a. The Great Deceleration and proposed alternative interpretation of the Anthropocene. Episodes, 44, 107-114.

Nielsen, R.W., 2021b. Anthropogenic data question the concept of the Anthropocene as a new geological epoch. Episodes, preprint, https://doi.org/10.18814/epiiugs/2021/021020

Nirei, H., Furuno, K., Osamu, K., Marker, B., Satkunas, J., 2012. Classification of man-made strata for assessment of geopollution. Episodes, 35, 333-336.

Oliveira, A.M. dos S., Peloggia, A.U.G., 2014. The Anthropocene and the Technogene: stratigraphic temporal implications of the geological actions of humankind. Quaternary and Environmental Geosciences, 5(2), 103-111.

von Pávai-Vajna, F., 1911. Über den Löß des siebenbürgischen Beckens. Jahresbericht der königlich-ungarischen Geologischen Reichsanstalt, 1909, 226-250.

Pavlov, A.P., 1922. Epoques glaciaires et interglaciaires de l'Europe et leur rapport a l'histoire de l'homme fossile. Byulleten' moskovskogo obshchestva ispytatelei prirody, Otdel geologii, Novaya seriya, 31, 23-76.

Periman, R.D., 2006. Visualizing the Anthropocene: Human land use history and environmental management. In: Aguirre-Bravo, C., Pellicane, P.J., Burns, D.P., Draggan, S. (eds.). Monitoring Science and Technology Symposium: Unifying Knowledge for Sustainability in the Western Hemisphere. Fort Collins, US Department of Agriculture, 558-564.

Petrbok, J., 1929. Die holozänen Mollusken der Hochfläche bei Bela über dem Meer in Bulgarien. Archiv für Molluskenkunde, 61, 288-290.

Petrbok, J. 1939. Die Mollusken des unteren Holozäns von Celakovice an der Elbe. Archiv für Molluskenkunde, 71, 138-143.

Pillians, B., Gibbard, P., 2012. The Quaternary Period. In: Gradstein, F.M., Ogg, J.G., Schmitz, M., Ogg, G. (eds.). The Geologic Timescale 2012, Amsterdam, Elsevier, 979-1010.

Reboul, H., 1833. Géologie de la Période Quaternaire et Introduction a l'Histoire Ancienne. Paris, F.G. Levrault, 222pp.

Ruddiman, W.F., 2003. The atmospheric greenhouse era began thousands of years ago. Climatic Change, 61(3), 261-293.

Ruddiman, W.F., 2013. The Anthropocene. Annual Review of Earth and Planetary Sciences, 41, 4.1–4.24.

Ruddiman, W.F., 2018. Three flaws in defining a formal 'Anthropocene'. Progress in Physical Geography: Earth and Environment, 42(4), 451–461.

Ruddiman, W.F., He, F., Vavrus, S.J. & Kutzbach, J.E., 2020. The early anthropogenic hypothesis: A review. Quaternary Science Reviews, 240, 106386.

Rull, V., 2016a. The Humanized Earth System. The Holocene, 26(9), 1513-1516.

Rull, V., 2016b. The 'Anthropocene': A requiem for the Geologic Time Scale? - Quaternary Geochronology, 36, 76-77.

Rull, V. , 2021. The Anthropozoic era revisited. Lethaia, 54(3), 289-299.

Sando, W.J., 1989. HUM Lithosome: An example of regional stratigraphic synthesis in the Mississippian of the Western Interior Region of the United States. U.S. Geological Survey Bulletin, 1881, E1-E17.

Sherlock, R.L., 1922. Man as a Geological Agent: An Account of His Actions on Inanimate Nature. London, H.F. and G. Witherby, 372pp.

Simpson, G.G., 1949. The Meaning of Evolution. A Study of the History of Life and of its Significance for Man. New Haven, Yale University Press, 364pp.

Steffen, W., Grinevald, J., Crutzen, P., McNeill, J., 2011. The Anthropocene: conceptual and historical perspectives. Philosophical Transactions of the Royal Society A, 369(1938), 842-867.

Steffen, W., Broadgate, W., Deutsch, L., Gaffney, O., Ludwig, C., 2015. The trajectory of the Anthropocene: The Great Acceleration. The Anthropocene Review, 2, 81-98.

Steffen, W., Leinfelder, R., Zalasiewicz, J., Waters, C.N., Williams, M., Summerhayes, C., Barnosky, A.D., Cearreta, A., Crutzen, P., Edgeworth, M., Ellis, E.C., Fairchild, I.J., Galuszka, A., Grinevald, J., Haywood, A., Ivar do Sul, J., Jeandel, C., McNeill, J.R., Odada, E., Oreskes, N., Revkin, A., Richter, D. deB., Syvitski, J., Vidas, D., Wagreich, M., Wing, S.L., Wolfe, A.P., Schellnhuber, H.J. 2016. Stratigraphic and Earth System approaches to defining the Anthropocene. Earth's Future, 4, doi:10.1002/2016EF000379.

Stoppani, A., 1873. Corso di Geologia, Volume II. Milano, G. Bernadoni e G. Brigola, 880pp.

Suess, E.,1862. Der Boden der Stadt Wien nach seiner Bildungsweise, Beschaffenheit, seinen Beziehungen zum bürgerlichen Leben. Eine geologische Studie. Vienna, Wilhelm Braumüller, 326pp.

Ter-Stepanian, G., 1988. Beginning of the Technogene. Bulletin of the International Association of Engineering Geology, 38, 133-142.

Thober, B., 2019. "Natur unter Menschenhand"? Zur Historisierung des Anthropozoikum-Konzepts von Hubert Markl im Hinblick auf die aktuelle Anthropozän-Debatte. Revue d'Allemagne et des pays de langue allemande, 52(2), 303-319.

Toivanen, T., Lummaa, K., Majava, A., Järvensivu, P., Lähde, V., Vaden, T., Eronen, J.T., 2017. The many Anthropocenes: A transdisciplinary challenge for the Anthropocene research. The Anthropocene Review, 4(3), 183-198.

Vézian, A., 1863. Prodrome de Géologie. Tome Premiere. Paris, La Société Géologique de France, 662pp.

Vézian, A., 1865. Prodrome de Géologie. Tome Troisième. Paris, La Société Géologique de France, 728pp.

Vohland, A., 1914. Der schneckenführende Elstermergel von Rüssen-Storkwitz. Sitzungsberichte und Abhandlungen der Naturwissenschaftlichen Gesellschaft Isis in Dresden, Jahresbericht, 1913, 12-26.

Waters, C.N., Syvitski. J.P.M., Gałuszka, A., Hancock, G.J., Zalasiewicz, J., Cearreta, A., Grinevald, J., Jeandel, C., McNeill, J.R., Summerhayes, C, Barnosky, A., 2014a. Can nuclear weapons fallout mark the beginning of the Anthropocene Epoch? Bulletin of the Atomic Scientists, 71(3), 46-57.

Waters, C.N., Zalasiewicz, J.A., Williams, M., Ellis, M., Snelling, A.M. (eds.), 2014b. A stratigraphical basis for the Anthropocene. Geological Society, London, Special Publications, 395, 1-321.

Waters, C.N., Zalasiewicz, J., Summerhayes, C., Fairchild, I.J., Rose, N.L., Loader, N.J., Shotyk, W., Cearreta, A., Head, M.J., Syvitski, J.P.M., Williams, M., Wagreich, M., Barnosky, A.D., An, Z., Leinfelder, R., Jeandel, C., Gałuszka, A., Ivar do Sul, J.A., Gradstein, F., Steffen, W., McNeill, J.R., Wing, S., Poirier, C., Edgeworth, M., 2018. Global Boundary Stratotype Section and Point (GSSP) for the Anthropocene Series: Where and how to look for potential candidates. Earth-Science Reviews, 178, 379-429.

Williams, M., Zalasiewicz, Waters, C.N., Landing, E., 2014. Is the fossil record of complex animal behaviour a stratigraphical analogue for the Anthropocene? In: Waters, C.N., Zalasiewicz, J.A., Williams, M., Ellis, M., Snelling, A.M. (eds.). A stratigraphical basis for the Anthropocene. Geological Society, London, Special Publications, 395, 143-148.

Wheeler, H.E., Mallory, V.S., 1956. Factors in lithostratigraphy. Bulletin of the American Association of Petroleum Geologists, 40(11), 2711-2723.

Whewell, W., 1853. Of the Plurality of Worlds: An Essay. London, John W. Parker and Son, 296pp.

Wolterstorff, W., 1938. Hermann Löns als Zoologe. Abhandlungen und Berichte aus dem Museum für Naturkunde und Vorgeschichte in Magdeburg, 6, 369-381.

Zalasiewicz, J., 2008. The Earth After Us: What Legacy Will Humans Leave in the Rocks? Oxford, Oxford University Press, 256pp.

Zalasiewicz, J., 2013. The unique inner landscape of the Anthropocene. EGU General Assembly, Geophysical Research Abstracts, 15, EGU2013-1015.

Zalasiewic, J., Williams, M., Smith, G., Barry, T., Coe, A., Brown, P., Brenchley, P., Cantrill, D., Gale, A., Gibbard, P., Gregory, F., Hounslow, M., Kerr, A., Pearson, P., Knox, R., Powell, J., Waters, C.N., Marshall, J., Oates, M., Stone, P., 2008. Are we now living in the Anthropocene? GSA Today, 18, 4-8.

Zalasiewic, J., Williams, M., Waters, C.N., 2014. Can an Anthropogenic Series be defined and recognized? In: Waters, C.N., Zalasiewicz, J.A., Williams, M., Ellis, M., Snelling, A.M. (eds.). A stratigraphical basis for the Anthropocene. Geological Society, London, Special Publications, 395, 39-53.

Zalasiewic, J., Waters, C.N., Wolfe, A.P., Barnosky, A.D., Cearreta, A., Edgeworth, M., Ellis, E.C., Fairchild, I.J., Gradstein, F.M., Grinevald, J., Haff, P., Head, M.J., Ivar do Sul, J.A., Jeandel, C., Leinfelder, R., McNeill, J.R., Oreskes, N., Poirier, C., Revkin, A., Richter, D. deB., Steffen, W., Summerhayes, C., Syvitski, J.P.M., Vidas, D., Wagreich, M., Wing, S., Williams, M., 2017. Making the case for a formal Anthropocene Epoch: an analysis of ongoing critiques. Newsletters on Stratigraphy, 50(2), 205-226.

Zalasiewicz, J., Waters, C.N., Williams, M., Summerhayes, C. (eds), 2019a. The Anthropocene as a Geological Time Unit: A Guide to Scientific Evidence and Current Debate. Cambridge, Cambridge University Press, 362pp.

Zalasiewicz, J., Waters, C.N., Head, M.J., Poirier, C., Summerhayes, C.P., Leinfelder, R., Grinevald, J., Steffen, W. Syvitski, J., Haff, P., McNeill, J.R., Wagreich, M., Fairchild, I.J., Richter, D.D., Vidas, D., Williams, M., Barnosky, A.D., Cearreta, A., 2019b. A formal Anthropocene is compatible with but distinct from its diachronous anthropogenic counterparts: A response to W.F. Ruddiman's 'three flaws in defining a formal Anthropocene'. Progress in Physical Geography: Earth and Environment, 43(3), 319-333.

Zalasiewicz, J., Waters, C.N., Ellis, E.C., Head, M.J., Vidas, D., Steffen, W., Thomas, J.A., Horn, E., Summerhayes, C.P., Leinfelder, R., McNeill, J.R., Gałuszka, A., Williams, M., Barnosky, A.D., Richter, D. de B., Gibbard, P.L., Syvitski, J., Jeandel, C., Cearreta, A., Cundy, A.B., Fairchild, I.J., Rose, N.L., Ivar do Sul, J.A., Shotyk, W., Turner, S., Wagreich, M., Zinke, J., 2021. The Anthropocene: Comparing its meaning in geology (chronostratigraphy) with conceptual approaches arising in other disciplines. Earth's Future, 9(3), e2020EF001896.