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Did anthropogeology anticipate the idea of the Anthropocene?

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Abstract

The term anthropogeology was coined in 1959 by the Austrian geologist Heinrich Häusler. It was taken up by the Swiss geologist Heinrich Jäckli in 1972, and independently introduced again by the German geologist Rudolf Hohl in 1974. Their concept aimed at mitigating humankind's geotechnical and ecological impact in the dimension of endogenic and exogenic geologic processes. In that context anthropogeology was defined as the scientific discipline of applied geology integrating sectors of geosciences, geography, juridical, political and economic sciences as well as sectors of engineering sciences. In 1979 the German geologist Werner Kasig newly defined anthropogeology as human dependency on geologic conditions, in particular focusing on building stone, aggregates, groundwater and mineral resources. The severe problems of environmental pollution since the 1980s and the political relevance of environmental protection led to the initiation of the discipline 'environmental geosciences', which – in contrast to anthropogeology – was and is taught at universities worldwide.

Keywords

Anthropocene, anthropogeology, engineering geology, environmental geology, mankind as geologic factor, prognosis, shift of paradigm, stakeholder

The roots of anthropogeology: Humankind as a geologic factor

Since the 1850s a number of scientists have become aware of the important role of humans in the present geologic cycle, and termed humankind as a geological and geomorphological force (Hamilton and Grinevald, 2015; Häusler Jr, 2016; Lewis and Maslin, 2015; Lowenthal, 2016, Steffen et al., 2007; Trachtenberg, 2015; Zalasiewicz et al., 2011). In 1854 the Welsh geologist and professor of theology Thomas Jenkyn termed the present-day human epoch and human-life rocks as anthropozoic, and in 1863 the US-American geologist James Dwight Dana (1813–1895) wrote a manual of geology entitled the *Age of Mind and Era of Man* (quoted from Lewis and Maslin, 2015).

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In 1862 the Austrian geologist Eduard Suess (1831–1914) mapped urban strata as a geological unit ('Schuttdecke') recording changes in the anthropogenetic strata of Vienna (Suess, 1862; Zalasiewicz et al., 2017a). Dorsch (2004, 2011, 2013) suggested that the book *Der Boden der Stadt Wien* (Suess, 1862) should be considered as the historical foundation of the geoscience branch of urban geology. In 1864 the US-American diplomat and philologist George Perkins Marsh (1801–1882) published a book with the title *Man and Nature: or, Physical Geography as modified by Human Action* (Marsh, 1864) and in 1865 the Irish mathematician, geologist and priest Samuel Haughton (1821–1897) published a new *Manual of Geology* and introduced the Anthropocene as the epoch in which we live (Lewis and Maslin, 2015).

The history of modern geology dates back to the early 19th century when the mining industry and the Industrial Revolution stimulated geologic investigations and surveying. It was the German geologist Carl Bernhard von Cotta (1808–1879) who published five editions of a textbook on present-time geology (*Geologie der Gegenwart*). He noted the present role of geology as an interface between the past and the future and emphasised the interrelationship between geology, astronomy, chemistry, biology and sociology ('Zu zeigen, wie die Geologie mit allen zusammenhängt … ist eine Hauptaufgabe der Geologie der Gegenwart'; Cotta, 1866, 1878). In 1871 the geologist of the Austrian Empire, Dionýs Štúr (1827–1893), wrote a book on the geology of Styria wherein he referred to anthropozoic formations (*Die anthropozoischen Formationen*, Stur, 1871). He was followed by the Italian priest and geologist Antonio Stoppani (1824–1891), who introduced the idea of the 'anthropozoic era' in 1873 (Stoppani, 1873). In 1914 the Russian geologist and palaeontologist Aleksei Petrovich Pavlov (1854–1929) wrote another paper on 'Recent geology' (Starodubtseva, 2006) and according to Vernadsky (translated in Ivanov, 1997) Pavlov termed this current period an 'anthropogenic era', emphasising: '… that man, under our very eyes, is becoming a mighty and ever-growing geological force'.

In 1916, the German geologist Ernst Fischer published a paper on mankind as a geologic factor (*'Der Mensch als geologischer Faktor'*; Fischer, 1916) – about 90 years before Paul Crutzen newly introduced the aspects of 'geology of mankind' (Crutzen, 2002). In his paper Ernst Fischer already quantitatively highlighted the environmental changes caused by humans in the dimension of geologic processes such as lowering the groundwater table for agriculture, deforestation causing erosion and karstification, and rapidly increasing consumption of raw mineral materials worldwide due to increasing population. Also, Ernst Fischer emphasised the potential impact of humans, modifying the climate to more continental conditions with an increase of extreme weather events in Europe.

A few years after Ernst Fischer's paper the British geologist Robert Lionel Sherlock (1875–1948) published another contribution on *'Man as geological agent: an account of his action on inanimate nature'* (Sherlock, 1922), which was an impressive work describing human activities in altering the Earth's surface to suit their needs with abundant statistical data on Great Britain and comparisons with countries worldwide. A few years passed before the regional and global dimension of human influence was again compared to the dimension of geologic processes. In 1926, the Russian-born polymath and philosopher Vladimir Ivanovich Vernadsky (1863–1945) published a Russian edition of *The Biosphere*, parts of which were published in an American journal in 1945 entitled: *'The Biosphere and the Noösphere'* (Vernadsky, 1945). According to the Internet Encyclopaedia, the term noosphere (or noösphere) derives from the Greek words 'nous' for mind and 'sphaira' for sphere and means 'the sphere of human thought'. Vernadsky (1945: 9) concluded that the noösphere was a new geological phenomenon on our planet, noting: 'Mankind taken as a whole is becoming a mighty geological force'. In 1956 the geologist William Leroy Thomas Jr published about the Greco-Roman civilisation (from about 1100 BC to AD 565) and the human impact on the natural environment entitled: *'Man's role in changing the face of the Earth'* (Thomas Jr, 1956).

Fischer (1916) and Häusler (1959) also quantified the anthropogenic impact and its socio-economic implications on our environment and compared it with the dimension of natural endo- and exogenic geologic processes. As a consequence Häusler (1959) introduced 'anthropogeology' as an applied geologic discipline focusing on humankind as a geologic factor. The term anthropogeology is composed of the Greek words 'ánthrōpos' for human and 'logos' for study, and Heinrich Häusler emphasised the relationship between humans and geologic processes not only in the past and present but also in the near future. In this respect anthropogeology introduced a new facet of geology; in contrast to traditional geology, which was considered a more historically oriented science (Zeil, 1975), modern textbooks on geology give prominence to the human impact on system Earth as geologic factor (e.g. Bahlburg and Breitkreuz, 2004). In 1983 Dov Nir published a book *Man, A Geomorphological Agent*, introducing anthropic geomorphology (Nir, 1983), and he referred to geomorphologic concepts of forerunners of, e.g. Marsh (1864), Woeikof (1901a, 1901b), Fischer (1916), Sherlock (1922), and others.

Interestingly, it was Robert V (Bob) Davis Jr, an experienced senior-level US government advisor with degrees in Political Science, Public Administration, History, and Science and Technology in Society, who recently highlighted the needs of geological prognosis. Davis (2011) noted: 'Nineteenth-century geologists were concerned with using the then-current geological state of affairs to understand the Earth's past, and acknowledged that an improved understanding of the past could provide clues to the forces presently at work, but projections into the future were largely absent'.

From the statements provided above it can be deduced that fundamental changes of our environment were and are due to the management of mining, industry, water works, agriculture, and development of cities. As such, these changes are caused by communities and regional politicians as well as by stakeholders in city planning, trade and economy.

It was not a geoscientist but the Nobel Prize-winning atmospheric chemist, Paul Crutzen, who perceived the influence of human behavior on Earth in recent centuries as so significant as to constitute the 'Anthropocene' as a new geological era, which he described as (Crutzen, 2002): '… widely used … to denote the present time interval, in which many geologically significant conditions and processes are profoundly altered by human activities. These include changes in: erosion and sediment transport associated with a variety of anthropogenic processes, including colonisation, agriculture, urbanisation and global warming …'. By introducing *Geology of Mankind*, Paul Crutzen (2002) explicitly described mankind as a geologic factor in a wider sense and in the dimension of geologic processes. In the next section examples are given that the human interference in the global geologic cycle exceeds or at least equals naturally known geologic processes. For future geotechnical and environmental planning it can be problematic to rely on actualistic processes, which do not take human-induced influences on geology into consideration. The worldwide population, humans and humankind have emerged as geologic factors significantly influencing the geologic cycle and thus our entire environment.

Man as geomorphologic and geologic agent: A new perspective

For people at an average citizen level it is difficult to imagine that the world's population can act as a 'human force' equal to natural forces, or that mankind is acting as a geomorphologic and geologic agent. This is not surprising considering that even well-known scientists such as Guido Visconti (University of Aquila and Center of Excellence on Integration of Remote Sensing Techniques and Numeric Modelling for the Forecast of Severe Weather) have a poor understanding of the geological impact, as can be inferred when he argues that the manifestations of the human influence on the landscape are widespread, but confined only to the first few metres of depth and primarily to soils (Visconti, 2014). Though many geologists and even applied geologists continue to doubt the dimension of the anthropogenic influence on the Earth, the increase of human activities since the Industrial Revolution in the 1750s – and more significantly since the 1950s – have occurred parallel to the observed dramatic change which is termed 'Great Acceleration' (Steffen et al., 2004).

The yearly impact of mankind equals or exceeds exogenic geological processes of, e.g. erosion, transport and deposition as quantified by Wilkinson (2005; compare to Leinfelder and Schwägerl, 2012), Syvitski et al. (2005), Syvitski and Kettner (2011), Lewis and Maslin (2015) and others. Man-made earthquakes can be caused by the construction of large reservoirs (Klose, 2012, 2013) or the injection of wastewater into deep boreholes can trigger the release of tectonic stresses in the Earth's crust (Müller, 1970). Moreover, recent decades have experienced strategic bombing, including nuclear weapons and nuclear tests (Hamblin, 2013), setting free enormous destructive power equalling the dimension of endogenic geologic processes (Sandiford, 2012).

In the following a few striking calculations are presented to indicate that mankind must be considered a geomorphologic and geologic agent. Concerning exogenic geologic processes Wilkinson (2005) calculated that Earth's agricultural land is currently being denuded at a mean rate of ~643 m per million years (my). This is ~28 times faster than deep-time erosion rates inferred from natural processes in the dimension of 24 m/my. In conclusion, by approx. 1000 AD human-induced soil erosion was equal to the natural erosion of about 5 billion tonnes per year. The amounts of weathering debris composing continental and oceanic sedimentary rocks indicate that mean denudation over the past half-billion years of Earth history has lowered continental surfaces by a few tens of meters per million years. In comparison, construction and agricultural activities currently result in the transport of enough sediment and rock to lower all ice-free continental surfaces by a few hundred meters per million years. According to the geologist Roger LeBaron Hooke (2000), mankind has now arguably become the premier geomorphic agent sculpting the landscape, and the rate at which we are moving earth is increasing exponentially. Giving an example, at the present in the USA humans move ~30 tonnes of earth per capita annually, the worldwide average amounts to ~6 tonnes per capita. By multiplying the values of the average amount of earth moved per capita during last 5000 years by population at the respective times in the past, Hooke estimated that the total amount of earth moved, both intentionally and unintentionally, would be sufficient to build a 4000-m-high mountain range, 40 km wide and 100 km long. If current rates of increase persist, the length of this mountain range would be doubled in the next 100 years (Hooke, 2000).

Douglas and Lawson (2001) reported that, on a global scale, the deliberate shift of around 57,000 megatons per year (MT/yr) of material through mineral extraction processes exceeds the annual transport of sediment to the oceans by rivers (some 22,000 Mt/yr) by nearly a factor of three (Price et al., 2011). While the export of sediment to oceans by rivers is 10 Mt/yr, the export of materials in solution is about 40 Mt/yr, making the deliberate material shift nearly 14 times larger than the shift caused by natural processes.

The following data illustrate that the present impact of human activities worldwide also exceeds major endogenic geologic processes. According to the Australian geologist Mike Sandiford (2012), the total energy system being developed by humans matches the energetic of predominant Earth processes because human energy consumption equals that of plate tectonics in the terawatt (1 TW = 10^{12} W) scale. Big earthquakes release energy in the scale of quadrillion joules (QJ). Mega earthquake systems operate at about 10 GW, which is similar to the energy associated with the uplift and formation of huge mountain belts (such as the Himalayas, the growth of which spanned 50 million years). The total human energy used on the globe is about 12

TW. At the current rate of consumption, by 2060 the human energy system shall be comparable to the global energy system driving plate tectonics. In terms of the energy released during the Hiroshima nuclear bomb (1 hiro = 60 TW), the current human energy system is equal to 0.25 hiro and the plate tectonic system is equal to 0.75 hiro. By the end of the century, human activity would be consuming energy at 1 hiro and the energy system associated with the warming of oceans since 1990 is an alarming 5 hiro (Sandiford, 2012).

According to Haff (2010, 2014a, 2014b), technology is also considered a geological phenomenon, and the technosphere, the interlinked set of communications, transportation, bureaucratic and other systems that act to metabolise fossil fuels and other energy resources, is considered to be an emerging global paradigm. Concrete and modern plastics are two examples of the technofossil record of humans, the preservable material remains of the technosphere, quoted by Zalasiewicz et al. (2014), who states that the current global production of modern plastics such as polyethylene and polypropylene is in the range of 270 Mt per year, and for concrete an annual 3.4 billion tonnes (and rising). Further impressive data on the mass of major components of the physical technosphere is presented by Zalasiewicz et al. (2017b).

The intention of this paper is not to deflate the significance of the proposed new geological epoch as discussed by Hamilton and Grinevald (2015) but to document fundamentals of anthropogeology, a discipline hardly known – even to geologists. The following examples of proponents favouring anthropogeology in the second half of the last century illustrate the basic considerations of socio-economic and political implications, and the an-actualistic approach of predicting geologic and ecologic changes caused by large geotechnical projects.

European proponents of anthropogeology 1956–1979

In this section, curricula vitae of four European geologists dealing with anthropogeology (a–d) are briefly reviewed. The basic ideas of Heinrich Häusler (1959) were followed up by Heinrich Jäckli (1972). Both Rudolf Hohl (1974) and Werner Kasig (1979) also developed ideas about anthropogeology but independently, not based on Häusler or Kasig. In order to distinguish between the two different views on anthropogeology, the fundamentals of Heinrich Häusler, Heinrich Jäckli and Rudolf Hohl are summarised as ‘anthropogeology 1’ and the ideas of Werner Kasig are termed ‘anthropogeology 2’. All four of these geologists were not ‘anthropo-geologists’ as such but dealt with applied geologic projects and emphasised the interaction between humans and geologic processes at both local and regional scales. In the 1980s the dimension of environmental problems motivated Kasig and Meyer (1984) to introduce the term ‘environmental geology’ instead of anthropogeology (e).

(a) Heinrich Häusler (Austria, 1959)

Heinrich Häusler (12 April 1919–11 June 2007) studied geology at Vienna University and received his PhD in 1940. During the Second World War he served as a military geologist and in 1948 he founded a ‘Technical Bureau of Applied Geology, Theoretical Geology and Anthropogeology’. From 1952 to 1957 he cooperated with the renowned engineering geologist Josef Stini (Stiny), who headed the Department of Technical Geology at Vienna University of Technology. Heinrich Häusler became an expert for geologic investigations for hydropower projects and dams serving the highest waterlaw-authority in Austria. From 1957 to 1964, in addition to his technical bureau, he was employed as an assistant at the Department of Technical Geology at the Vienna University of Technology. Based on geologic-technical and ecological investigations for hydropower projects in Upper Austria, he wrote a paper on the impact of humans on geologic processes (*'Das Wirken des Menschen im geologischen Geschehen'*, Häusler, 1959) and coined 'anthropogeology' as a new discipline of applied geology. It was the German geologist of Rostock University, Kurd von Bülow, who wrote the following in the foreword to Häusler's publication: 'Man darf die bisherige Vernachlässigung der "Anthropo-Geologie" seitens der geologischen Fachwelt daraus erklären, dass die Länge des "anthropozoischen" Zeitraumes weit unter erdgeschichtlichen Maßen liegt', which means that a previous lack of regard for 'anthropo-geology' is understandable considering that the short duration of the 'anthropocoic' time span is far below geologic scales.

The fundamental idea of anthropogeology in the sense of Heinrich Häusler was the study of geologic processes at a local scale to understand the human impact of large geotechnical projects on endogenic and exogenic geologic processes as a basis for the prognosis of such interactions and hence proper planning of the geotechnical project. This concept basically anticipated environmental impact assessment, which evolved in the 1960s as part of an increasing environmental awareness. What Heinrich Häusler proposed was a change of paradigm for geology, taking a fundamentally historically oriented science and turning it into an applied science focusing on the prediction of geological and ecological processes in the near future. This meant more or less providing methods and tools for quantitatively analysing geologic and ecologic systems and hence of exogenic and endogenic processes in an extended project-area within a time span of at least 100 years or until the end of the operational life of geotechnical projects such as large tunnels or hydropower projects. In addition, such prognosis implied an actualistic geologic assessment of the construction site in the planning phase and the non-actualistic assessment of human-induced processes in the geologic system until the end of the construction phase and beyond. Hence, Heinrich Häusler emphasised that the detailed study of the local geologic cycle comprising lithosphere, pedosphere, hydrosphere and atmosphere lies in the responsibility of the geologic consultant.

Heinrich Häusler published two papers on the responsibility of geologic experts, the first on the essential geologic prerequisites for the responsibility in geotechnical engineering (Häusler, 1962a), and the second on the question of responsibility in engineering geology (Häusler, 1962b). For geotechnical projects three-dimensional visualization of the subsurface was provided, based on detailed geologic and geophysical mapping. Evaluation of actual geologic processes was based on special geomorphologic mapping and short- and long-term monitoring of environmental changes of the construction site and its surroundings. In addition, prognosis of the long-term behavior of the geotechnical project within the geologic system was supported by laboratory experiments. In the 1960s and 1970s methods in anthropogeology were developed that are explained in more detail in the section on 'Anthropogeology in the 1980s'.

(b) Heinrich Jäckli (Switzerland, 1972)

Heinrich Jäckli (22 December 1915–3 March 1994) studied geology at ETH Zurich, received his diploma in 1938 and his PhD in 1940. During wartime he became a military geologist and in July 1945 he founded a 'Bureau for Geologic Expertises'. He published many applied geologic papers, e.g. about Quaternary geology related to civil engineering (Jäckli, 1962) and the relation between groundwater and hydrology for hydropower projects (Jäckli, 1967). In 1964 Heinrich Jäckli wrote a contribution on mankind as a geologic factor (Jäckli, 1964), and in 1972 he published a paper on the *'Elements of Anthropogeology'* (Jäckli, 1972). His concept of anthropogeology resembled that of Häusler (1959), emphasising the relations between humans and geologic processes in the past, the present and in the future.

(c) Rudolf Hohl (German Democratic Republic – GDR, 1974)

Rudolf Hohl (17 August 1906–26 June 1992) studied geology at Leipzig University and received his PhD in 1932. During the Second World War he served as a military geologist and in 1949 he was employed at the Geological Survey in Leipzig. From 1951 to 1962 he taught applied geology at Martin-Luther University in Halle/Saale and hydrogeology at the Mining University of Freiberg. From 1960 on he headed the Geological Department of Halle University. In 1974 he published a paper on anthropogeology as a new discipline covering geology, geography, technical sciences and economy related to territorial planning of the former GDR (Hohl, 1974). It is not known if Rudolf Hohl was aware of previous publications on anthropogeology because he did not cite papers by Häusler (1959) or Jäckli (1972). However, Rudolf Hohl's ideas on anthropogeology resembled those previously mentioned: emphasizing the mutual relationship between humans as an active geologic factor and the geologic environment for concrete technical projects and also noting the need for investigation, prognosis and control of human impacts (Hohl, 1974). In his paper on anthropogenic endo- and exodynamics he also presented a detailed university course on 'Territorial Geology', also known as spatial anthropogeology, which included lectures in general and special natural sciences, geology, geography, applied geosciences, engineering sciences and anthropogeology.

(d) Werner Kasig (German Federal Republic – GFR, 1979)

Werner Kasig (*1936) studied geology in Freiberg/Sachsen, Aachen and Bonn, received his PhD in 1967 and his professorship in 1980. He became university professor for geology, first at Essen University and later on at Aachen University. In 1979 Werner Kasig published his ideas on anthropogeology '*as a new and important discipline within the geosciences*' (Kasig, 1979), emphasizing the political importance of geologists as mediator between raw materials economy and environmental protection. Compared with previous definitions (Häusler, 1959; Hohl, 1974; Jäckli, 1972) Werner Kasig newly defined anthropogeology as the '*dependence of humans on geologic conditions*', focusing on building stone, groundwater and mineral raw materials in particular (Kasig, 1979, 1984).

(e) From anthropogeology to environmental geology

It can be inferred that the increase of environmental problems in Germany in the 1980s, both in number and magnitude (in particular the geologic investigations for the underground storage of radioactive waste: Kasig, 1985) caused another change of terminology from an – at that time in Germany hardly promoted and in German language difficult to pronounce and spell 'Anthropogeologie' – towards the much better understandable term 'Umweltgeologie'. Diethard E Meyer (*1938) also studied geology, received his diploma in 1964 and his PhD at Bonn University in 1969. From 1975 on he has been employed at Essen University, engaged in environmental geology, in particular mining landscape remediation (Meyer, 1986) and environmental protection (Meyer, 2002). Timely paralleling Kasig's (1984) contribution to anthropogeology, Kasig and Meyer (1984) published their fundamental paper on the basics, tasks and aims of 'Umweltgeologie' in Germany. They defined 'Umweltgeologie' (here in English translation) as 'The science of humankind's dependency on the geological environment and the effect of humankind's interference in the geological cycle with all its interdependencies in the abiotic and biotic spheres in the past, present and future' ('Lehre über die Abhängigkeit des Menschen von der geologischen Umwelt und über die Auswirkungen seines Eingriffs in den geologischen

Kreislauf mit allen Wechselwirkungen im abiotischen und biotischen Bereich in Vergangenheit, Gegenwart und Zukunft').

Thus, environmental geology (in close context with anthropogeology as well as prospective geology in the sense of Lüttig, 1976) was designed as integrating scientific discipline in the circle of geosciences, geography, juridical and economic sciences as well as parts of engineering sciences. Yet it is exactly this interaction between humans and geologic environment, defined as the core competence of environmental geology by Kasig and Meyer (1984, 1994), which had already been regarded as fundamental in the earlier concepts of anthropogeology as promoted by Häusler (1959), Jäckli (1972) and Hohl (1974).

The geologist Ulrich Rosenfeld analysed the different concepts of anthropogeology published to that time (Rosenfeld, 1992). On the one hand he considered it in its forecasting sense, coping with geologic impacts caused by humans (Häusler, 1959; Hohl, 1974; Jäckli, 1972), and on the other hand as the dependency of humans on geologic conditions in the sense of Kasig (1979). Ulrich Rosenfeld (*1930) began studying geosciences at Münster University in 1953, received his PhD in 1957 and his professorship in 1966. From 1958 on he was employed at the university and he became a professor at Münster University in 1970. Ulrich Rosenfeld (1992) favoured the term environmental geology as defined by Kasig and Meyer (1984) but concluded that from the academic point of view environmental geology was more a commercial service than a scientific discipline. In addition, Rosenfeld argued that anthropogeology as a scientific discipline would become obsolete because it was not being taught at European universities. He proposed a new kind of actualistic geologic research as a discipline to investigate recent exogenic and endogenic geologic processes in the geosphere, which should be of use for the prognosis of anthropogenic impacts on the lithosphere relevant to environmental research.

Figure 1 illustrates the fundamental ideas of anthropogeology in the sense of Häusler, Jäckli and Hohl ('anthropogeology 1'), and in the sense of Kasig ('anthropogeology 2') as well as the basic ideas of environmental geology (Kasig and Meyer) and of neo-actuogeology (Rosenfeld). Rosenfeld's disapproval of anthropogeology did not spell its end as a scientific discipline, although in the 1980s further ideas were published more in conference proceedings rather than in international journals.

Anthropogeology in the 1980s

Timely paralleling the concept of 'anthropogeology 2' (Kasig, 1984), and the initiation of environmental geology (Kasig and Meyer, 1984), further statements on this specialised field of applied geology and 'anthropogeology 1' were made by Heinrich Häusler. Presentations were given at the Conference of the German Geologic Society in 1984 under the favourite topic 'Anthropogeology – humans as geologic factor' (Häusler, 1985), at an Austrian symposium on the 'Perspectives of Evolution and Technology' in 1986 (Häusler, 1986), at an International Congress of the 'General Certified Court Experts' of Austria in 1987, and at an 'International Seminar for Experts and Lawyers' in 1988 (Häusler, 1988). In 1988 Heinrich Häusler described anthropogeology as the research discipline for the knowledge of and information on the living space of mankind endangered by natural and human-induced processes. As the object of anthropogeologic research he considered the connection between geological structures and processes and the spectrum of historic activity and recent impact of humankind (Häusler, 1988).

The proposed change of paradigm in geology from a historically oriented to a more prognosticating science remained more or less unseen among experts, with few exceptions (e.g. Lüttig, 1976). Figure 2 depicts a tentative schematic sketch of geologic research for purposes of production and

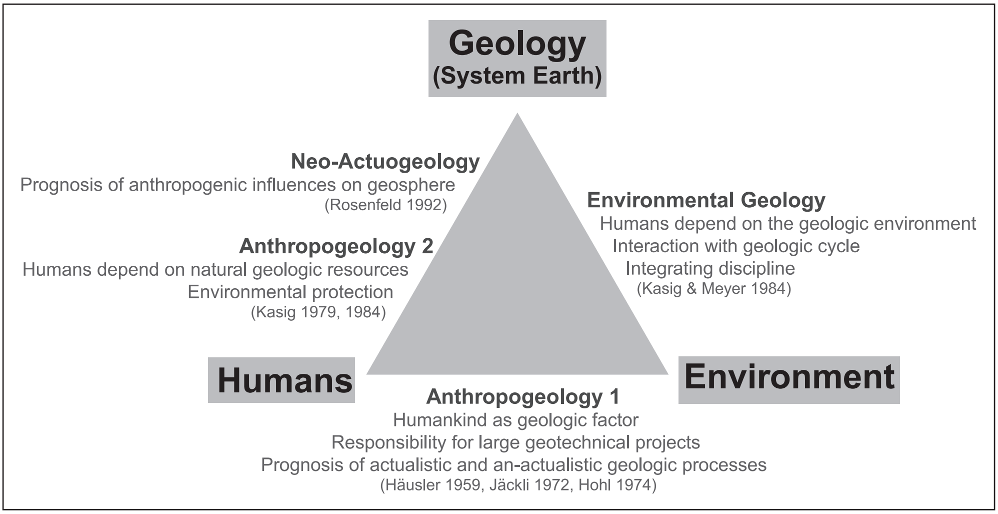

Figure 1. Graphic illustration of the two different concepts of anthropogeology, of environmental geology and neo-actuogeology in the context between geology, humans and environment (modified from Häusler Jr, 2016).

economy. Accordingly, the application of geology for the investigation and exploitation of mineral resources and fossil fuels cumulated in the 20th century and a decline in the following decades was presumed. In comparison, further research on anthropogeology and its methods for prognosticating geological processes, was expected to emerge in the 21st century.

In addition to the basic ideas on anthropogeology published in 1959, Heinrich Häusler presented more detailed comments in the 1980s comprising methodological improvements in applied geology and in particular engineering geology, more interdisciplinary but also transdisciplinary academic education, and aspects of regional politics at state government level (Häusler, 1988). As a consequence, Heinrich Häusler advised the State Government of Upper Austria in important economic projects such as large water reservoirs combined with nuclear power plants. Therefore, his anthropogeologic expertise included assessment of both the geological and ecological systems focusing on economic variants regarding socio-economic implications for the state governmental politicians (Figure 3).

Figure 3 depicts a system approach of the 1980s on basic interrelations of the environmental system depending on the final political decision on the variant of a geotechnical project. Heinrich Häusler concluded that the geotechnical project remains the only constant within these functional relations. Numerous expert opinions of Heinrich Häusler proved that the methods of engineering geology provided by his 'Technical Bureau of Applied Geology, Theoretic Geology and Anthropogeology' persuaded the project managers or lawyers either to provide a larger budget for the prognosis of environmental geologic processes or to take more responsibility for calculated risks. To sum up, methods of anthropogeology in the 1980s were successful for investigating future geologic processes and ecologic change of the environment (Figure 2).

As already mentioned above, in the 1980s the term anthropogeology was replaced by the term environmental geology (Kasig and Meyer, 1984, 1994). Since then numerous disciplines have developed which investigate both the system Earth – from the geological point of view – and the Earth system – from the system-oriented point of view. Owing to the fact that our planet Earth is

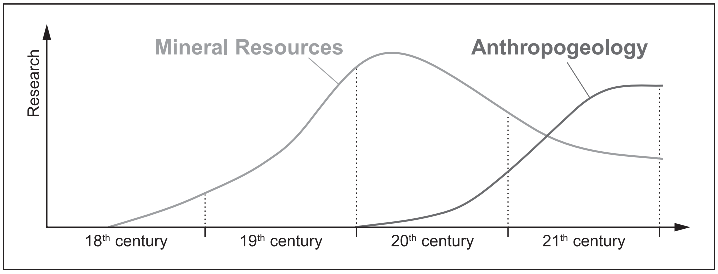

Figure 2. Heinrich Häusler assumed a significant shift of research in applied geology from the investigation of mineral resources in the 19th and 20th centuries toward political implementation of anthropogeology in the 21st century (modified from Heinrich Häusler, 1988).

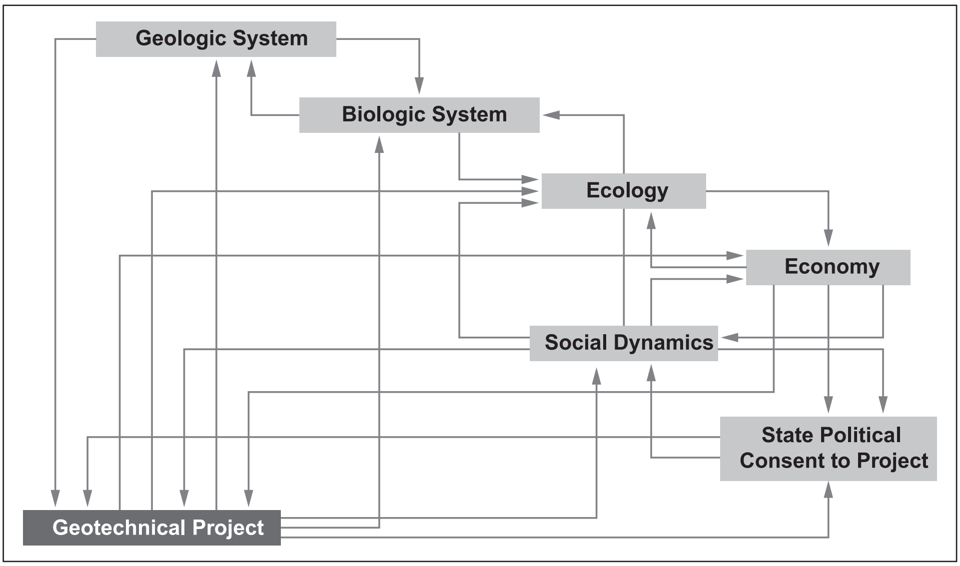

Figure 3. Tentative systems approach of interdependencies between a geotechnical project and its political consent. Once the concept of the geotechnical project has been decided, in contrast to all other factors, the project remains the constant factor within the system-analytical approach (modified from anthropogeologic expertises of Heinrich Häusler for the State Government of Upper Austria, 1983–1985).

investigated by differing scientific disciplines, the introductory texts for these various disciplines also differ. These sciences include but are not limited to geology and geography, applied geology and applied geography, environmental geology and environmental geography, anthropogeology and anthropogeography, environmental sciences and environmental system sciences as well as Earth System science (Ehlers and Krafft, 2001, 2006; Oldfield, 2016).

More recently Culshaw and Price (2011) argued that since the 1970s engineering geology has become much broader in its scope. Their paper on urban geology and city management is an important discussion on historical development of engineering geology and environmental geology in the context of human-geological interactions. Twentieth-century decade- to century-scale variations in parts of the Earth system as well as future scenarios at a decadal scale have been intensively discussed at the 96th 'Dahlem Workshop on integrated history and future of people on Earth' (Constanza et al., 2007). Since the first scientific assessment report on climate change was published by IPCC in 1990, other future global scenarios on human-induced atmospheric influence have also been calculated. Earth System science aims at quantitatively understanding the linkages, interactions, and feedbacks in human–environment relations. In contrast, modelling the processes of the system Earth is by far more difficult at a regional scale because of the scarcity and/or lack of data available. In this respect the wheel comes full circle – the anthropogeologic methods of the late 1980s allow for quantifying the relations between local endogenic and exogenic geologic processes and geotechnical projects for the prognosis of an environmental change at decadal timescale.

Such considerations may be still of relevance for future international projects such as geoengineering (Huttunen et al., 2015) or transboundary strategic environmental impact assessment. Environmental impact assessment is commonly defined as determining the (positive and negative) environmental consequences of a plan, policy, program, or concrete project prior to making a decision about whether or not to move forward with the proposed action. Environmental geoscientists were chosen for performing environmental impact assessment because they could best assess the natural and human-induced processes impacting the surface, subsurface and groundwater environment. For more detailed explanations and discussion on the nomenclature of environmental geology, applied geosciences and environmental geosciences it is referred to Matschullat and Müller (1994), Hilberg (2015), Häusler Jr (2009, 2016).

Discussion

The discussion in literature on the introduction of the Anthropocene is controversial. Despite the efforts and arguments of the Anthropocene Working Group for meeting the stratigraphic requirements of an informal or formal Anthropocene Epoch (Zalasiewicz et al., 2017a), scientists of many disciplines agree with or oppose the Anthropocene. On the one hand the time span of the Anthropocene is discussed as lasting from as early as when humans began to impact the Earth (e.g. Barnosky and Hadly, 2014; Barnosky et al., 2014), and on the other hand this epoch is reduced to several decades beginning with when data from global Earth observation stations allowed for analysing the Earth as a whole in terms of a system theoretical approach (Hamilton, 2016a, 2016b).

In this section I first discuss the use to distinguish between environmental geosciences investigating the system Earth and the recent paradigm shift toward Earth System sciences (ESS). The central object of investigations of both environmental geosciences and ESS is our planet Earth. Second, I argue that the introduction of the Anthropocene is useful, apart from the nomenclature discussion, because it strikingly accuses the human impact on the environment and hence is of socio-political relevance. Third, I present arguments as to why I am of the opinion that anthropogeology anticipated the idea of the Anthropocene.

(1) Environmental geosciences deal with the system Earth, in particular with its geosphere, pedosphere, hydrosphere (including cryosphere), biosphere (including anthroposphere and hence also technosphere) and atmosphere with the recent human impact on these spheres, as outlined in the anthropogeology section. For many geoscientists the idea that mankind is impacting system Earth in the dimension of geologic processes is still not self-evident and they often do not perceive that geomorphology is the result of both endogenic and exogenic processes including mankind as a geologic factor. For persons other than geoscientists this comparison between a natural geologic and a human-induced geologic impact might also not be convincing because on the one hand geologic processes in the Earth's development are known as very slow and long-lasting and on the other hand perceived as quick and devastating geo-processes such as

rock fall and earthquakes that are more described in terms of geomorphological or geophysical processes (Gaffney and Steffen, 2017: 54).

In literature the scope of Earth System science is also discussed conversely. On the one hand it is defined as encompassing the study of the environmental physical and life sciences and engineering, coupled with an analysis of human constructs and political and economic policies (Ernst, 2000). On the other hand, it is strictly related to human-caused changes in the functioning of Earth's systems as proofed by modelling the exponential increase of the human impact since the 1950s at global scale (e.g. Hamilton, 2015, 2016a, 2016b). Compared with modern methods of geosciences (including humans as a geologic factor) that investigate the spheres of the system Earth, the Anthropocene should be understood as a concept within the ESS, which has emerged from technological advances in data collection and processing and in the integration of historically distinct scientific disciplines (Hamilton, 2015; Trachtenberg, 2015). For understanding the paradigm shift from environmental geosciences to Earth System sciences it is of the essence to recognise that the Anthropocene cannot be described by results from various geosciences but can only be understood as a system-oriented conception within the Earth System sciences (Hamilton, 2015, 2016a, 2016b; Hamilton and Grinevald, 2015; Trachtenberg, 2015). In contrast, modern geosciences to a great dimension are still knowledge-driven sciences dealing with qualitative and quantitative local to regional modelling whereas ESS are defined as data-driven sciences using Earth science data techniques of the whole Earth as one single system and hence modelling at global scale (Hamilton, 2016b; Kempler and Mathews, 2017).

(2) The discussion on the introduction of the Anthropocene is apparently driven more by politics than science. According to Ellis and Trachtenberg (2014), the broad interest in the Anthropocene likely has a moral component and is based on a 'coming to terms' with human responsibility for the planet-wide changes caused by humankind. Thus, for some, the Anthropocene idea offers an occasion for passing judgement on humanity's domination of nature. Apart from the formal stratigraphic definition, the Anthropocene as a term cannot escape 'public and political resonance' (Gibbard and Lewin, 2016). Peppoloni and Di Capua (2016) emphasise that investigating, managing, and intervening on the geosphere implies ethical obligations. Although the German geologist Gösta Hoffmann argues against the introduction of a new stratigraphic unit, he admits that the term 'Anthropocene' is important to emphasise the partly irreversible human impact on the environment and is therefore of socio-political relevance (Hoffmann, 2017).

In my opinion, the special significance of accepting the Anthropocene lies in the fact that everybody can understand human impact on a global scale, if less in terms of the stratigraphic proof then more in terms of global change causing regional warming, glacier melting, the rise of sea levels, environmental pollution and so on. The human impact on the atmosphere, hydrosphere, cryosphere and biosphere since the 1870s is evident, and 'business as usual' is being questioned in the face of the 'Great Acceleration' that has been occurring since the 1950s because the human coupling with natural systems is irreversible (Hamilton, 2015). In the context of applied geology I believe that a definition of the geological timescale of the Anthropocene is of great importance because it signals that human activity can be seen as responsible for this new epoch (Ellis and Trachtenberg, 2014). I think that the acceptance of an 'Anthropocene Epoch', an age of humans, would enable environmental scientists and engineering geologists to act with more confidence in negotiations with decision-makers, despite not fundamentally doing anything different (Gill, 2016; Pearlman et al., 2014; Uhlenbrock et al., 2014; Wysession and Rowan, 2013). For this purpose experiences from anthropogeology as outlined in this paper could be useful.

(3) In discussing the question of whether or not anthropogeology anticipated the idea of the Anthropocene, I have one negative and four positive answers. In 'The human impact on geologic

processes – an introduction to anthropogeology' Heinrich Häusler explicitly linked anthropogeology with the anthropozoic period in order to signalise the worldwide human impact on the Earth in the 20th century. My answer to the question if anthropogeology anticipated the idea of the Anthropocene is therefore 'yes' because a handful of applied geologists emphasised the impact of humankind on Earth in a geologic dimension as was later again argued by Crutzen (2002).

A second "yes" to the question of whether anthropogeology anticipated the idea of the Anthropocene is evidenced by the fact that in the second half of the 20th century engineering geologists were already analysing complex geo-environmental processes in order to better understand the potential human impact, e.g. for the prognoses of the interaction of hydroelectric power plants, large construction sites, etc. with the local environment from the ecological and socio-economic point of view. Such prognoses were provided as the result of a multi-disciplinary, interdisciplinary and transdisciplinary approach. Knowledge on anthropogeologic projects at that time was, however, only seldom conveyed at universities or presented at congresses.

A third 'yes' for anticipating the term Anthropocene in the context with anthropogeology and thus engineering geology is because of the early awareness of responsibility as well as the ecologic-economic, socio-economic, and ethic implications of the anthropogeologic concept. The Holocene (Greek for 'entirely recent') is a term for a geologic epoch without any direct correlation to humans, whereas Anthropocene directly addresses those who are undoubtedly responsible for our human-induced environmental disasters. A fourth 'yes' to the idea of the Anthropocene is that it reflects a new epoch with an intimate connection between the Earth and humans, and geologists are well aware of how relevant the geosciences have become in tackling challenges to the future of humankind based on the two principles 'the present is the key to the past' and 'the past is the key to the present and future' (Tewksbury et al., 2013). My last answer in this context of whether the idea of the Anthropocene was anticipated by anthropogeology in terms of Earth System sciences, of course, is 'no'. ESS represents a fundamental new concept based on powerful computer calculations and modelling of data acquired from multitemporal and multisensor global observation systems as well as of socio-economic data. As a consequence, preparing such heterogeneous data, data reduction and data analysis falls within the scope and expertise of data scientists rather than geoscientists (Kempler and Mathews, 2017).

Regarding these aspects I argue that the term 'Anthropocene' is welcome because (today) it is easy to understand and its basics also are published in newspapers and gazettes signalling to everybody who is interested in facts that humans – at least since the 1950s – have impacted our planet Earth in a great dimension with negative consequences for us all and that human-induced climate change is one of these negative consequences. At the same time I am in complete agreement with the ethicist Clive Hamilton (Hamilton, 2016b) who argues that world politics are driving the global economy and that the ignorance of decision makers who do not realise or accept the facts presented by the Earth System sciences, or the regular reports of the Intergovernmental Panel on Climate Change respectively, should frighten us.

In this paper I recalled that in the second half of the 20th century a few applied geologists in German-speaking countries, namely Austria, Switzerland and Germany, recognised the tremendous impact of humankind on the environment and introduced anthropogeology as a new branch of applied geology. However, owing to the fact that the basics and experiences of anthropogeology were then hardly taught at European universities, the potential for integrated Earth sciences fell into oblivion. Ultimately, I am of the opinion that also in the ESS-driven epoch the importance of interdisciplinary (and transdisciplinary) environmental geosciences will remain of the essence for basic research on the qualitative interpretation of complex environmental processes, where data are scarce or missing.

Conclusions

Being aware of the socio-economic implications of the rapidly increasing world population in the 20th century, a few applied geologists in Europe were of the opinion that mankind could be considered a geologic factor comparable to the dimension of endogenic and exogenic geologic processes. Apart from any contribution to the stratigraphic definition of the Anthropocene, protagonists of anthropogeology emphasised responsibility of prognosticating the human impact on the geologic cycle, in particular on the lithosphere, pedosphere, hydrosphere and atmosphere of our planet Earth. In order to mitigate this impact on our environment their considerations ranged from responsible planning of large geotechnical projects such as hydropower projects, atomic power plants and waste deposits to the sustainable use of natural resources such as ground water, geothermal energy, fossil fuels and minerals raw materials. The role of geoscientists and in particular geologists for society is an important one. In his paper *'Role of geology in transition to a mature industrial society'* the US-American geologist and geophysicist Marion King Hubbert (1903–1989) noted (Hubbert, 1977): '… if it would be managed to conceive that the geological history, instead of ending with the Pleistocene, has a present and a future as well, it would then be possible for geologists to play again a leading intellectual role'. The question remains if and how this can be achieved.

As an extension of the three-dimensional geologic system at various scales, the prognosis of geological processes means more or less their extrapolation to the near future, which raised a change of paradigm in geology. Interestingly, this idea was accentuated by Robert V (Bob) Davis, who noted (Davis, 2011): 'While modern geologists still seek to know the present to understand the past, the notion of Anthropocene implies knowing the present to predict the future. And it is predicting that in the future, retrospective will show the present as having been geologically shaped by man'. In conclusion, anthropogeologic efforts during the second half of the 20th century aimed at inter- and transdisciplinary investigation of our natural environment for societal projects from local to regional scale worldwide. For these reasons it is inferred that anthropogeology, as the new geology of mankind, anticipated the following fundamental ideas of Crutzen and Stoermer (2000): 'Considering these and many other major and still growing impacts of human activities on earth and atmosphere, and at all, including global, scales, it seems to us more than appropriate to emphasize the central role of mankind in geology and ecology by proposing to use the term "Anthropocene" for the current geological epoch'.

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