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ORIGINAL ARTICLE

A geo-ethical logic for citizens and geoscientists

Martin Bohle[1,2]

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Abstract
The impacts of anthropogenic change do call for strengthening the socio-political and socio-economic anchorage of geoethical thinking. Geosciences are more than mere techno-scientific disciplines as, for example, geohydrology shows. Geoscience expertise ties geosciences and people's social lives. Geosciences are relevant for the societies' functioning, namely, to operate a technosphere at local, regional and planetary scales. Therefore, geoscience expertise includes a school of philosophical thinking called geoethics. Although initially designed for professional use, geoethics should support any citizen's individual, professional and civic dealings. Nowadays, the technosphere is a vital feature of the contemporary Earth System (or 'human niche'). In these contexts, conceptual benchmarks for geoethical thinking are described to address: (i) the operational limits of aspirational stipulations and (ii) a stronger socio-political anchorage of geoethical thinking. Methodologically, the present study relates geoethical thinking with the political philosophies of Bunge, Jonas and Kohlberg about people's social lives. Their works offer foundations for a broad application of geoethical thinking by providing benchmarks: Kohlberg's 'hierarchy of societal coordination (moral adequacy)', Bunge's 'balance of individual happiness (well-being) and duty' and Jonas' 'imperative of responsibility for agents of change'. These political philosophies can be combined with geoethical thinking (or geoethics). A 'geo-ethical logic' can be formulated, calling to act with: agent-centricity, virtue-focus, responsible-focus, reproducible/scientific knowledge, all-agent-inclusiveness and universal-rights-base. Whilst preserving the design of geoethics, the proposed geo-ethical logic strengthens the socio-political anchorage of geoethical thinking, and aspirational stipulations are benchmarked. Further study should aim to complement the given frame of socio-political benchmarks by socio-economic benchmarking.

Keywords Geoethics · Moral adequacy · Imperative of responsibility · Sense-making · Complex-adaptive · Social–ecological systems

Introduction

This essay discusses simple although abstract benchmarking for geoethical thinking.[1] It consolidates previous studies (Bohle 2021b; Marone and Bohle 2020) using the works of Kohlberg (1981) on a hierarchy of societal coordination (moral adequacy), of Jonas (1981) on an imperative of responsibility of agents of change (towards future generations) and of Bunge (1989) on the balance between (individual) happiness (well-being) and the duty to help.

The innovative element of the present study is to interpret the political philosophies of Kohlberg, Bunge, Jonas as benchmarks, for example, to buttress mere aspirational stipulations. To this end, geoethical thinking and philosophical insights of Kohlberg, Bunge, Jonas are brought into a joint description whilst preserving the given design of geoethics (Peppoloni et al. 2019). As a methodological approach, a 'geo-ethical logic' will be sketched. It offers an application of geoethical thinking like, some years ago, the 'geoethical promise' (Matteucci et al. 2014). The 'geo-ethical logic' is consistent with the application scope and emerging visions of geoethics; the latter, for example, including an aspirational framework called 'Responsible Human Development Charter' (Peppoloni and Di Capua 2020). Hence, the

✉ Martin Bohle
martin.bohle@ronininstitute.org

[1] Ronin Institute for Independent Scholarship, Montclair, NJ 07043, USA

[2] International Association for Promoting Geoethics (IAPG), Rome, Italy

[1] For the benefit of the reader, the word 'geoethics' is used for a specific configuration of geoethical thinking to distinguish variants of thought.

geo-ethical logic should be understood to complement an ongoing debate.

Initially, geoethical thinking emerged as a variant of responsible sciences (United Nations 2013; Peppoloni and Capua 2017; Gundersen 2018). Considering geoethical thinking for times of global anthropogenic change (Bohle and Bilham 2019) then led to questions about how geoethical thinking relate to concepts like the 'human niche' (Bohle and Marone 2019) or 'scientific culture' (Di Capua et al. 2021). Subsequently, recent developments in geoethics (Peppoloni and Di Capua 2020) aim to support any human agent acting in any professional or civic scope.

Regarding terminology, the notion of 'human niche' is a metaphor. It englobes the scientific concept of the 'anthropogenic biome' (Ellis et al. 2016; Fuentes 2017), respectively, 'social–ecological system', see for example (Colding and Barthel 2019). Associating the notions 'human niche' and 'Earth System' as synonymous acknowledges the Anthropocene as factual, regardless of whether being included in the geological time scale (Zalasiewicz et al. 2019). Nevertheless, the notions 'human niche' and 'Earth System' apply contextually; the notion 'Earth System' is process-oriented, and 'human niche' is holistic. The notion 'niche' carries the message 'one system' maintained or altered by the living beings that inhabit it. The metaphor 'human niche', or the scientific notions of the 'anthropogenic biome' and 'social–ecological system', emphasise the concept of a single, non-separable system of intertwined social and ecological processes. Hence, the thinking behind these notions is orthogonal to thinking using dichotomic concepts like '*Nature vs Culture*' or '*human interventions into natural systems*', which are often used when discussing ethics and geosciences.

This essay explores how to strengthen geoethical thinking by considering socio-political[2] dynamics as vital as geodynamics. To that end, the findings of three philosophers are applied. The following matters are taken as critical backgrounds:

- First, the human niche is understood as a network of social–ecological systems at the planetary scale with complex and adaptive dynamics. Nowadays, World and Nature combine into a single Earth System of non-separable parts, the human niche. The notion 'non-separable' expresses that system features get lost when the system is segregated into sub-systems. Hence, the contemporary Earth System (human niche) is more than the sum of its parts. Subsequently, *'normative guidance of human behaviours'* (for example, geoethics) is a non-separable system feature of the Earth System (human niche). It is part of the process to regulate the system by tuning human sense-making and subsequent action.
- Second, technological systems (Haff 2016) and the social, cognitive, cultural or political behaviours (Leach et al. 2018; Dryzek and Pickering 2019) of how societies handle resources, agents or technologies, (Hartley and Herrmann-Pillath 2018) are part of the human niche. Hence, the social, cultural or political interactions among people (human agents) are intrinsic parts of the human niche in the same way as, for example, soil, oceans, or metropolitan areas. The feedback between how people sense, observe and understand the features of the human niche and their action is part of the processes which form the human niche. Subsequently, *'normative guidance of human behaviour'* (for example, geoethics) is an intrinsic system component of any social–ecological system. Therefore, geoethical thinking and practices should be understood as an intrinsic, internal component of the human niche.
- Third, simplifying, humans intervene into existing (natural, social, technical) systems by deploying technologies, which is a mix of hard and soft artefacts, partly tangible partly intangible. Deploying a given technology is an intricate technical, economic, social and political process. It starts with making sense of what was happening and what ought to happen. It continues with intervening in existing systems (that is, deploying a technology). The process of human sense-making and deploying technology is a feedback loop. How to handle climate change can serve as an example (Edenhofer and Kowarsch 2015). The feedback of sense-making and action (e.g. deploying a technology) links the concepts of human niche and geoethical thinking because it is about a culture of *'how to act'* as a genuine part of the Earth System (human niche).
- Forth, the human niche-builder applies, among many other insights, geoscientific expertise. Geoethical thinking is rooted in geoscience expertise. Therefore, geoethical thinking is a specific contribution to the *'sense-making-action feedback loop'* because it uses (scientific) understanding of the natural dynamics of the Earth System (human niche). Subsequently, the question arises of how geoethical thinking uses (scientific) understanding of the social dynamics of the human niche (Earth System). In that context, other matters than geosciences have to be understood to master the feedback of *'sense-making and action'* (Boonstra 2016; Fuerth and Faber 2012); the public attitudes of to the geothermal energy can serve as a geoscience example (Meller et al. 2018).
- Fifth, any society takes enormous efforts to control, shape, maintain, twist or spin the sense given to events, actions, and things related to the deployment of tech-

[2] Considering socio-economic dynamics is subject of ongoing studies of the author.

nologies. The German *'Energiewende'* (a step-wise turn of German policy for the supply of energy away from nuclear energy) can serve as an example (Hake et al. 2015; Leinfelder 2017; Andersson and Törnberg 2018). Social–ecological systems exhibit complex-adaptive behaviour, which often prompts the perception of system behaviour as *'wicked'* (Bohle 2020). Likewise, the feedback loop of *'sense-making and action'* often binds people in a stable universe of perceptions (Salvatore et al. 2019a) that prevent their ideas and actions from being altered. Experience shows that scientific or technical expertise does not help much in such circumstances (Stewart et al. 2017).

Following the introduction, several concepts are introduced to argue for perceiving Earth and World as a single comprehensive system ("Social–ecological systems and sense-making"), human sense-making (such as geoethical thinking) included as an intrinsic non-separable subsystem. Subsequently, it is sketched how geoethical thinking was constructed and how it has evolved ("Reviewing the construction of geoethics") to describe it by four tenets (of geoethical thinking). This description leads to the research question: how to express explicitly the societal contexts inherent to geoethical thinking as additional (or modified) tenets. To that end, the political philosophies of Kohlberg, Bunge and Jonas are used to formulate the 'geo-ethical logic' ("Benchmarking the tenets of geoethical thinking"). Finally, the conclusions are presented ("Discussion and conclusion").

Social–ecological systems and sense-making

Across continents and oceans, natural processes and human practices are intertwined in socio-ecological systems. The intertwining is different in European landscapes (e.g. industrial agriculture) or at the coasts of Antarctica (e.g. adventure tourism), at the surface of the North Sea (e.g. wind energy parks) or in the depths of the Pacific Ocean (e.g. mining at the seabed). Although the intersections of natural processes and human practices are most prominent at local and regional scales, they cumulate to anthropogenic global change as a planetary feature (Syvitski et al. 2020). The global nitrogen cycle may serve as a less familiar example than climate change (Lade et al. 2020; Zhang et al. 2015).

Complex-adaptive social–ecological systems

Humankind operates a globalised system to supply food, commodities and goods. The means are, for example, social organization, deployment of technologies and engineering of infrastructures. The resulting global human niche is a network tightly knotted with multiple process loops, which can stabilise or destabilise the system dynamics (Walker et al. 2020). They create an intimate social and ecological dynamic (Schlüter et al. 2019; Donges et al. 2017) that often cannot be presented as the sum of its parts. The latter is a crucial feature of complex-adaptive dynamics.

The concepts of complex-adaptive dynamics and social–ecological systems are a powerful description of the (natural and societal) features of the human niche (Preiser et al. 2018). Social–ecological systems exhibit dynamical features like nonlinearity, threshold-dependent displacements of system stages, and positive feedback loops. Such features can cause complex-adaptive behaviour. Complex-adaptive systems are hard to handle, including that the system may behave contrary to the observer's expectations. Such counterintuitive system behaviour, which can be perceived as *'wicked'* (Head and Xiang 2016), includes: (i) multiplexed cause-and-effect paths, (ii) not proportional output-input relations, (iii) multifunctional structure, and (iv) amplifying interactions (Preiser and Woermann 2018).

In a first instance, the notion 'human practices' seems to refer to acts of individuals. However, human practices also encompass the governance arrangements of public bodies or corporations (Biermann 2014). Likewise, they englobe justifications (rational or affective) and decisions (by individuals, corporations or institutions). For example, governance arrangements determine how to design technologies, production systems, and consumption patterns (Chaffin et al. 2016; Kowarsch et al. 2016). The given societal processes (e.g. administrative, political, cultural) and related infrastructures (e.g. parliaments, ministries, foundations, think tanks) have a dual nature; namely, they combine a cognitive function (sense-making) and a material foundation (to enable the sense-making process). Hence, people's attitudes and behaviours within social–ecological systems have a material form that mirrors the cognitive processes of individuals, political bodies, social structures, and institutions. Such 'soft parts' of a social–ecological system co-shape the system dynamics and influence system behaviour (Galaz et al. 2011). They are essential as any technical artefact or natural process.

Sense-making in the human niche

People's sense-making of environments and their actions is a complex process. Some aspects are sketched in the following. They help relating geoethical thinking to the human niche's societal features.

Different human agents (individuals, collectives, corporates or institutions) may react in a variable way to the same system behaviour that they observe. The differences can arise because of different sense-making processes, including different views about *'what ought to happen'* or because of counterintuitive system behaviour (Head and Xiang

2016; Termeer et al. 2019). Beyond such differences, any human agent uses rational and affective cognitive processes to make sense of observations or insights and accordingly tuned actions. Usually, views about *'what ought to happen'* enable agents to handle what otherwise seems divergent or counterintuitive (Salvatore et al. 2019b). The notion of what ought to happen has a double meaning: first *'expected event'*, and second *'what should be done'*. Hence, *'what ought to happen'* is about the (factually) expected or (morally) right.

Considering building the human niche; simplifying, human agents deduce *'what to do'* from their observation and insights. For example, in the given context, deploying a given technology (e.g. for damming a river) to shape a specific feature of the human niche (e.g. to generate electric power, to irrigate cropland). Whatever a given individual or collective human agent chooses to do, it means performing (material, physical) actions based on assessments driven by given goals. In turn, the actions alter the natural or social environment. Subsequently, the altered environments prompt agents to re-assess the environments and, if needed, to take a new action. The sequence of assessments and actions results in a feedback loop between sense-making and action.[3] The human agent may be part of the environment that is altered. Such a feature renders the feedback process more complicated. Subsequently, it may be difficult to distinguish between *'the observed object'* and *'the observing subject'*. Hence, the specific features of the (individual or societal) sense-making processes are essential for the feedback between sense-making and action.

Considering making sense, sense-making of social–ecological features combines rational and affective cognitive processes (Fuerth and Faber 2012; Salvatore et al. 2018). When cognitively challenged, human agents (individual, collective, corporate, institutional) may distrust rational sense-making processes (e.g. scientific insights). As an alternative, they can use affective sense-making skills (Stewart and Lewis 2017). These skills are outcome-preconditioned and rational only within constraints. First, the constraint (psychological need) of keeping one's worldview coherent within the cultural environment to which the agent belongs (group pressure). Second, the constraint to work as an affect-laden, stable and pre-semantic scheme of given expectations. These two processes stabilise the outcome of sense-making. They bind the sense-making (of the agent) to the social and political processes with the function to ensure that occurs *'what ought to happen'* despite (external) conflicting inputs or alternative views.

Considering system features, individual sense-making, coordination of individuals, and governance system exhibit knotted processes and feedbacks. They aggregate various inputs, such as observations, conceptual insights, worldviews of 'what ought to be', or formal norms. It would be erroneous to reduce the dynamics of governance systems to the action of individuals (Dryzek 2016). The various human sense-making processes are part of the social–ecological systems, even if it is difficult to model them jointly with other system features (Otto et al. 2020). For the following discussion, a simple conceptual understanding is enough. Namely, an effectively designed [geo]ethics can shape rational and affective human sense-making, learning, coordination and action; that is, that occurs *'what ought to happen'*. That is what [geo]ethics is about, be it as professional ethics (Di Capua et al. 2017) or more (Peppoloni and Di Capua 2020).

Reviewing the construction of geoethics

Geoethical thinking (in geosciences) has various roots (Bohle and Di Capua 2019; Raab and Frodeman 2002; Di Capua et al. 2021). Like other STEM disciplines (United Nations 2013; Paul 2018), geosciences have considered their societal contexts. Initially, geoethical thinking promoted professional codes. Subsequently, frameworks such as the definition of geoethics (Peppoloni and Di Capua 2012), the *'Geoethical Promise'* (Table 1), or the *'Cape Town Statement on Geoethics'* (Di Capua et al. 2017) were formulated some years ago.

Aspirational frameworks such as the geoethical promise support codified professional practices. They guide the individual behaviours of every person and have the potential for outreach in society (e.g. Hippocratic oath). By its subject, geoethical thinking can address a more comprehensive community than professional geoscientists (Moores 1996; Peppoloni et al. 2019). Moreover, agent-centricity can also be conceived as collective or institutional agents instead of considering individuals.

The Cape Town Statement on Geoethics (Di Capua et al. 2017) was formulated at the 35th International Geological Congress (held in 2016 at Cape Town) as a step towards a broader application of geoethics. The statement describes geoethics as agent-centric, responsibility-focussed, and knowledge-based, and it is considered virtue ethics with the geoethical promise as a central feature. The Cape Town Statement on Geoethics also describes the societal contexts of geosciences (although without mentioning social organisation or historical development) as *"to enrich the roles and responsibilities of geoscientists towards communities and the environments in which they dwell"*. It continues, *"[h]uman communities will face great environmental challenges in the future. Geoscientists have know-how that is essential to orientate societies towards more sustainable practices in*

[3] …system behaviour >> sense-making >> action >> system behaviour >> sense-making >> action >> …

Table 1 The geoethical promise (Matteucci et al. 2014)

Nine statements
… I will practice geosciences being fully aware of the societal implications, and I will do my best for the protection of the Earth system for the benefit of humankind
… I understand my responsibilities towards society, future generations, and the Earth for sustainable development
… I will put the interest of society foremost in my work
… I will never misuse my geoscience knowledge, resisting constraint or coercion
… I will always be ready to provide my professional assistance when needed, and I will be impartial in making my expertise available to decision-makers
… I will continue the lifelong development of my geoscientific knowledge
… I will always maintain intellectual honesty in my work, being aware of the limits of my competencies and skills
… I will act to foster progress in the geosciences, the sharing of geoscientific knowledge, and the dissemination of the geoethical approach
… I will always be fully respectful of Earth processes in my work as a geoscientist

Table 2 Tenets of geoethical thinking (adapted from (Marone and Bohle 2020))

Tenets	Meaning
1. Agent-centricity	To apply a normative framework that invests (empowerment) an individual professional geoscientist to act to their best understanding in the face of given circumstances, opportunities and purposes
2. Virtue-focus	A corpus of personal traits (honesty, integrity, transparency, reliability, or spirit of sharing, cooperation, reciprocity) of an individual professional geoscientist that furthers operational (handling of things) and social (handling of people) capabilities of the individual
3. Responsibility focus	The outcome of a normative call (internal, external) upon an individual professional geoscientist to frame decisions/acts in terms of accountability, as well for the intended effects as for unintended consequences
4. Knowledge-base	In the first and foremost instance, apply geosciences/Earth system knowledge; acquired by scientific methods instead of allusion to faith or 'authorities'

our conscious interactions with the Earth system. Applying a wider knowledge-base than natural sciences, geoscientists need to take multidisciplinary approaches to economic and environmental problems, embracing (geo)ethical and social perspectives." (Peppoloni 2018) (p. 6).

On these foundations, the state-of-the-art description of geoethics (Peppoloni et al.2019) aggregates various concepts around the notion of *'responsibility'* (of the individual geoscientist). A school of thought has emerged considering deontological features (Marone and Marone 2014), training (Mogk and Bruckner 2020), commercial activities (Nurmi 2017), relational values and law (Aragão 2021)), or political philosophy (e.g. *'Responsible Human Development Charter'* (Peppoloni and Di Capua 2020)).

Summarising the construction of geoethical thinking: (i) A detailed design of geoethics is available (see Fig. 1 and 2 in (Peppoloni and Di Capua 2020)). The exhaustive corpus of works about geoethics offers detailed descriptors, such as detailing the traits of the individual's virtuous behaviour. Several open issues have been identified recently (Bohle and Di Capua 2019). Also, the broader embedding of geoethics has been explored (Bohle and Marone 2021). However, a review of geoethical thinking or geoethics from an external perspective is not available yet.

Tenets of geoethical thinking

In the given context of constructing geoethics, this essay attempts to present a generic and straightforward, although conceptual, description of geoethical thinking (Table 2). Geoethical thinking can be described as promoting four tenets (Marone and Bohle 2020): agent-centricity, virtue-focus, responsibility-focus, and geoscience-knowledge.

The first, second and third *'tenet of geoethical thinking'* could inspire any scientist or concerned citizen. However, the fourth tenet about the knowledge-base is more specific set by geosciences. It identifies knowledge-domain and, as a procedure, the scientific methods to acquire knowledge. Initially, the knowledge-domain of geoethics was described as discipline-specific, namely to deal "*with the ethical, social and cultural implications of geoscience education, research and practice, and with the social role and responsibility of geoscientists in conducting their activities"* (Peppoloni and Di Capua 2017) (p. 2). In later publications, a somewhat broader knowledge domain got mentioned (Di Capua and Peppoloni 2019).

The phrasing of the tenets of geoethical thinking does not refer to any benchmarks that may guide the human agent. Instead, the human agent must assume responsibility

because (Peppoloni et al. 2019) (p. 30) *"experience confirms that choices that are taken in a specific social and cultural setting, that respect the ethical norms of this setting, may appear unethical elsewhere. Thus, the apparent relativism of geoethics, referred to above, has its roots in a fundamental feature of virtue ethics. How to handle such* [pluralism] *is an ethical dilemma of geoethics".*[4] That degree of freedom or *'option of normative pluralism'* is an intentional feature. Hence, by design, ethical thinking does not explicitly apply formal frameworks. In the current design, the option of normative pluralism put the onus on the human agent who takes decisions. Therefore, studying a utilitarian geoethics compared to a geoethics of justice may be rewarding.

The option of normative pluralism gives geoethics plasticity to operate in different contexts. Although this plasticity is an opportunity, it comes with the risk of decision overload for the human agent. Still, geoethical thinking is implicitly incorporating formal ethical frameworks. As illustrated by Hourdequin (2015) (p. 55) for environmental ethics: *"utilitarianism directs our attention to consequences; Kant's ethics to respect and autonomy; Aristotle's virtue ethics to character and its connection to living well"*. In geoethical thinking, Kantian and Aristotelian views shine through; hence geoethical thinking tacitly embeds formal ethical frameworks. Utilitarian views appear in geoethical thinking when the societal mission of geosciences is considered. In that sense, the Cape Town Statement on Geoethics specifies that geoscientists are "*primarily at the service of society. This is the deeper purpose of their activity.*" (Di Capua et al. 2017) (p. 6). Furthermore, some works in geoethics referred to questions of justice, diversity and equality, mainly when tackled as intra-disciplinary matters such as relations with colleagues (Mogk 2020; Bohle and Di Capua 2019).

The current definition of geoethics and a research question

The current 'definition of geoethics' is "*(a) human agent-centric, (b) shaped as virtue-ethics, (c) geoscience knowledge-based, (d) with space–time context dependent approaches. Geoethics is a virtue ethics, placing at the forefront individual, responsible action based on the adoption of societal and professional reference values… Geoethics is grounded on geoscience knowledge to assure an informed and conscious approach to problems related to human-Earth system interaction. Geoethics is context-dependent in space and time and ethically sound choices may differ for similar ethical dilemmas: geoethics is shaped and informed by a strong awareness of the technical, environmental, economic, cultural and political limits existing in different socio-ecological contexts."* (Di Capua and Peppoloni 2019). Compared to earlier versions, this description of geoethics is more detailed. It also ties geoethics and the societal features of the human niche.

The four tenets of geoethical thinking (Table 2) are consistent with the current description of geoethics, except that *"[it] is shaped and informed by a strong awareness of the technical, environmental, economic, cultural and political limits existing in different socio-ecological contexts"*. This statement abridges the societal bonds of the geosciences and integrates it into the scope of geoethics, although with brevity. Therefore, the research question: how to express explicitly such societal bonds of geosciences as additional (or modified) tenets of geoethical thinking?

Benchmarking the tenets of geoethical thinking

The study of humankind's socio-economic and cultural practices shows how to tie geosciences (including geoethical thinking or geoethics) and the Earth System's societal features. Opportunities to explore these practices are many; for example, hydrogeology (Abrunhosa et al. 2021; Di Baldassarre et al. 2019; Sivapalan 2015). The work of Alexandra Aragão gives an example (Aragão 2021). She works on cultural ecosystem services, relational values and law. A recent study exemplifies how to work empirically and bottom–up to detail how geoethical thinking relates to societal features of the human niche. Instead of such empirical studies, a complementary approach that sketches a philosophical frame will be used here. Further empirical studies should fill this frame.

The following analysis uses the essence of the geosciences' societal contexts, namely the prospect to deliver expertise on how to make the technosphere working for building the human niche (Rosol et al. 2017; Dyer-Witheford 2018). To abridge that prospect, *"geosciences are instrumental in making anthropogenic global change happen. Therefore, geoscientists are its co-architects"* (Bohle and Bilham 2019) (p. 5). This statement must be qualified; nevertheless, it can serve as a simplified bottom line and the argument ties directly to the works of Jonas about the responsibility of agents of change. To illustrate what is meant: no anthropogenic climate change would have happened without geoscientists finding coal, oil, and minerals, forecasting weather for shipping commodities worldwide, estimating natural hazards for infrastructures or ensuring the stability of building foundations, etc.

In short, geoscience knowledge combined with engineering skills and capitalist mode of production led to the building of global supply chains that merged regional and local

[4] The term 'relativism' was replaced by 'pluralism' to sharpen the meaning.

social–ecological systems into a planetary human niche. The outcome is a global socio-economic infrastructure that some call *'technosphere'* (Redman and Miller 2015; Donges et al. 2017). The notion of a technosphere, however, should not be curtailed to denote hardware. On the contrary, affective insights, mental concepts and theoretical constructs are paramount for the technosphere because they are the software that leads to designing a given technical artefact and the specificities of how to deploy it (Haff 2016, 2017; Hartley and Herrmann-Pillath 2018). Hence, geosciences are essential to make technology working as part of the Earth System, hence enabling human agents to build the human niche. That is the essence of the specific societal contexts of the geosciences (Bohle 2021a) in distinction from other fields of knowledge.

To further exemplify the geosciences' societal contexts, the notion *'sustainability'* can serve as an illustration of how *'hardware'* and *'software'*, including ethics, relate in a single concept (Shearman 1990; Knight 2015; Leach et al. 2018). Sustainability is one of the four social values of geoethics (Peppoloni et al. 2019) (p. 48ff). It encapsulates that the (individual, collective, corporate or institutional) *'niche builder'* conceives, designs and operates the technosphere considering the needs of present and future generations. Simply put, sustainability means having a societal practice to ensure that the benefits that stem from the geo-endowments of the human niche last. Geo-endowments are, for example, air, water, soil, fuels, minerals, and biodiversity or ecosystem services. Societies *'harvest'* (that is, appropriate) geo-endowments through the technosphere. Whether a given geo-endowment is beneficial for none, some or many are the outcomes of choices, such as technological artefacts, mode of deployment, allocation of resources and gains, exposure to risks and hazards, and relations of power. Hence, the notion sustainability refers to hardware and software, namely, affective associations, mental concepts and theoretical constructs, and finally, normative frameworks for the organisation of society.

What to learn from the philosophers Jonas, Bunge and Kohlberg?

The methodological question arises as to what kind of philosophical description of the societal organization can be used to match two purposes: First, to expresses the societal contexts of geosciences in general terms. Second, to amend the tenets of geoethical thinking whilst keeping the design of geoethics.

So far, geoethical thinking has expressed societal contexts mainly through aspirational stipulations such as the *'geoethical promise'* (Matteucci et al. 2014) or, recently, the *'Responsible Human Development Charter'* (Peppoloni and Di Capua 2020). They are addressing the individual person. They appeal and therefore influence sense-making and action. However, exceptions apart, aspirational stipulations are feeble tools in general societal contexts, such as handling power relations (Natural Editorial 2018; Turnhout et al. 2020). In such circumstances, the human agent must refer to social organisation, historical development or societal contexts to buttress aspirational claims through benchmarking.

Recent analyses of geoethical thinking (Marone and Bohle 2020) indicate how such benchmarks for aspirational stipulations may be designed using political philosophy:

- The development of geoethical thinking begins with obligations that relate to Kant's Categorical Imperative (Williams 2018). However, Kantian ethics is considered incomplete (Weber 1919, 2015) because it does not consider the human agent's responsibility.
- Kohlberg's scale of moral adequacy ranks forms of societal cooperation. The degree and motivation of cooperation offer a benchmark for human behaviours and practices (Kohlberg 1981).
- Bunge's moral principle, balancing the right to (individual) happiness (well-being) by the duty to help human and other biological forms of life, offers a benchmark for the individual action (Bunge 1989)
- Jonas' imperative of responsibility (Jonas 1976, 1981) calls for intergenerational caretaking. It offers a benchmark for the responsible application of geoscientific expertise in times of anthropogenic global change, putting the onus on the agent of change who designs and deploys technology.

Geoethical thinking benefits from these philosophical concepts because they describe benchmarks (e.g. kind of cooperation, happiness vs duty, present vs future generations), which help the human agent to frame aspirational stipulations by balancing individual rights and duties, acting at a specific level of societal coordination, and exemplifying the needs of future generations. By applying these concepts of political philosophy, geoethical thinking will explicitly handle the societal contexts of the geosciences. Subsequently, geoethical thinking may edge towards considerations of social organisation and historical development, work still to be done.

Two words of warning before reformulating the tenets of geoethical thinking; first, it is debatable that advancing geoethical thinking needs additional concepts, such as, for example, the concept of a social contract (Serres 1995). As discussed, geoethical thinking kept a cautious pluralism regarding formal frameworks, like utilitarianism. Geoethical thinking stays at a meta-level of practical wisdom.[5] Second, the intended methodology may not meet the requirements of political sciences because it fails to analyse

[5] https://plato.stanford.edu/entries/aristotle-ethics/.

Table 3 The tenets of a geo-ethical logic (adapted from Bohle 2021b; Marone and Bohle 2020))

Tenets	Meaning
1. Agent-centricity	To apply a normative framework that invests (empowerment) a human agent (individual/group/institution) to act to their best understanding in the face of given circumstances, opportunities and purposes, and balancing happiness and duties
2. Virtue-focus	A corpus of traits (honesty, integrity, transparency, reliability, or spirit of sharing, cooperation, reciprocity) of a human agent (individual/group/institution) that furthers operational (handling of things) and social (handling of people) capabilities of the individual/group
3. Responsibility-focus	The outcome of a normative call (internal, external) upon a human agent (individual/group/institutions) that frames decisions/acts in terms of accountability, as well for intended effects as for unintended consequences and implications for current and future generations
4. Knowledge-base	In the first and foremost instance, [geosciences/Earth system] knowledge that is acquired by scientific methods; experience-based (indigenous/traditional/local) knowledge is a secondary instance; reproducibility of knowledge by third parties supports any claim of trustworthiness instead of allusion to faith or 'authorities'
5. All-agent inclusiveness	Achieve a practice of a *'shared social license to operate'* (metaphor) between various agents (individuals/groups/institutional) by mitigating differentials of power, voice etc. using participatory processes and capacity building
6. Universal-rights-based	Guide affective and rational sense-making of human agents (individuals/groups/institutions) by furthering cooperation and adherence to human rights (life, liberty, justice); to strengthen appropriately secondary normative constructs such as utilitarian, sustainability, precautionary principles or rights of non-human sentient beings and nature

production, accumulation and consumption (Dyer-Witheford 2018; Homer-Dixon et al. 2015). It is acknowledged, these modes put constraints on the freedom of the individual to decide, a crucial precondition for sound geoethical practices (*"[the] fundamental prerequisite is the freedom to be able to choose"*) (Peppoloni and Di Capua 2020) (p. 17).

Sketching a geo-ethical logic

Previous studies (Bohle and Marone 2019; Bohle 2021b) explored how to use Bunge, Jonas and Kohlberg's works. This study extends them to revise the tenets of geoethical thinking (Table 2). Together, the revised tenets (Table 3) describe a logic of geoethical practices (short: *'geo-ethical logic'*), namely to act with agent-centricity, virtue-focus, responsibility-focus, [geo]science-knowledge-base, all-agent-inclusiveness, and universal rights-basis.

The phrasing of the tenets of a geo-ethical logic is chosen to align with the core of geoethics, namely *"reflection on the values which underpin appropriate behaviours and practices, wherever human activities interact with the Earth system"* (Peppoloni and Di Capua 2015) (p. 4–5). Compared to previous studies, the phrasing of the tenets of a geo-ethical logic has been adjusted to represent the societal contexts of geosciences and set benchmarks to buttress aspirational stipulations.

The comparison of the phrasing of the tenets of geoethical thinking and the geo-ethical logic illustrates the following developments (Table 4):

- First, the individual human agent (a professional geoscientist) is replaced by a general concept of human agency (individual/collective/institutional). That change is the essential alteration of the first three tenets. It brings forward the insight that geoethical thinking should address any kind of human agency and acknowledges that reduction of human agency to the act of individuals is not appropriate. A comprehensive concept of human agency seems appropriate for anthropogenic global change. It goes beyond the perception of human agency habitually used in geoethics (see, for example, (Peppoloni and Di Capua 2020), p. 25, bottom first column).
- Second, additions are made to the first and third tenets to bring benchmarking capabilities. Drawing on Bunge's work, a reference is made in the first tenet (on agent-centricity) to happiness (well-being) and duties of the individual. Drawing on Jonas' work, the current and future generations are mentioned explicitly in the third tenet (on responsibility-focus).
- Third, the knowledge-domain of the human agent (tenet four) is broadened. The discipline-specific domain is replaced by a general reference to knowledge acquired by scientific methods, although geosciences and Earth sciences are mentioned in brackets. These sciences are singled out as essential within a much wider corpus of relevant knowledge because they enable Earth System stewardship (Bohle and Bilham 2019).
- Fourth, tenets five and six are added, making explicit some tacit concerns of geoethical thinking. For example, the notion of sustainability is supported through tenets five and six. These two tenets derive from Kohlberg's work on appropriate cooperation mechanisms (moving up a scale of moral adequacy). Higher levels of moral adequacy correspond to advanced forms of cooperation and therefore benchmark human practices.

Table 4 Comparison of phrasing: Tenets of geoethical thinking (Cape Town Statement) vs Tenets of geo-ethical logic

Tenets	As in: 'Geoethical thinking', e.g. formulated in the Cape Town Statement on Geoethics	As in: 'Geo-ethical logic'
1. Agent-centricity	To apply a normative framework that invests (empowerment) an individual professional geoscientist to act to their best understanding in the face of given circumstances, opportunities and purposes	To apply a normative framework that invests (empowerment) a human agent (individual/group/institution) to act to their best understanding in the face of given circumstances, opportunities and purposes, and balancing happiness and duty
2. Virtue-focus	A corpus of personal traits (honesty, integrity, transparency, reliability, or spirit of sharing, cooperation, reciprocity) of an individual professional geoscientist that furthers operational (handling of things) and social (handling of people) capabilities of the individual	A corpus of traits (honesty, integrity, transparency, reliability, or spirit of sharing, cooperation, reciprocity) of a human agent (individual/group/institution) that furthers operational (handling of things) and social (handling of people) capabilities of the individual/group/institutions
3. Responsibility-focus	The outcome of a normative call (internal, external) upon an individual professional geoscientist to frame decisions/acts in terms of accountability, as well for the intended effects as for unintended consequences	The outcome of a normative call (internal, external) upon a human agent (individual/group/institutions) that frames decisions/acts in terms of accountability, as well for intended effects as for unintended consequences and implications for current and future generations
4. Knowledge-base	In the first and foremost instance, apply geosciences/Earth system knowledge acquired by scientific methods instead of allusion to faith or 'authorities'	In the first and foremost instance, [geosciences / Earth system] knowledge that is acquired by scientific methods; Experience-based (indigenous/traditional/local) knowledge is a secondary instance; Reproducibility of knowledge by third parties supports any claim of trustworthiness instead of allusion to faith or 'authorities'
5. All-agent inclusiveness	n.a.	Achieve a practice of a *'shared social license to operate'* (metaphor) between various agents (individuals/groups/institutional) by mitigating differentials of power, voice etc. using participatory processes and capacity building
6. Universal-rights base	n.a	Guide affective and rational sense-making of human agents (individuals/groups/institutions) by furthering cooperation and adherence to human rights (life, liberty, justice); to strengthen appropriately secondary normative constructs such as utilitarian, sustainability, precautionary principles or rights of non-human sentient beings and nature

The tenets of geo-ethical logic, like the tenets of geoethical thinking, are not ranked. Depending on the application case, the relative weight of a specific tenet may vary. That feature reflects the pluralism characterising geoethical thinking. The human agent's obligation to choose how to apply the tenets in each given circumstance is an incentive to gain empowerment, although it comes with a risk of decision overload.

The tenets of the geo-ethical logic, like the tenets of geoethical thinking, are specified at a meta-level with a significant 'portion' of pluralism because they do not precondition normative frameworks. The exception is explicitly ruling out the allusion to *'faith'* or *'authorities'* (people of power) as a source of trustworthiness. Instead, *'reproducibility of knowledge'* is prescribed as a unique source of trustworthiness, a requirement that centres on science.

Acknowledging 'pluralism by design', the tenets relate to different formal ethical frameworks. As examples: the tenets *'agent-centricity', 'virtue-focus', 'all-agent-inclusiveness'* together emphasise the significance of the human agent (Kantian ethics); the tenets *'responsibility-focus'* and *'knowledge-base'* allow to qualify a given action (Utilitarian ethics); the tenets *'all-agent-inclusiveness'* and *'universal rights-base'* refer to the ethics of equality and justice. Hence ranking the tenets in a given circumstance implies switching between different formal ethical systems.

Compared to the initial tenets of geoethical thinking, the tenets of the geo-ethical logic should strengthen the application scope of geoethical thinking. The geo-ethical logic incorporates the societal contexts of the geosciences more explicitly and at a systemic level. In that sense, the geo-ethical logic offers a generic cultural substrate to support any human agent (geoscientist or citizen; individual or institutional) in navigating the human niche. Hence, the combination of geoethical thinking with reflections on the grade of societal coordination (Kohlberg), the balance of happiness and duty (Bunge), and responsibility towards future generations (Jonas) should strengthen the operational guidance offered by geoethical thinking.

Discussion and conclusion

As shown above, geosciences are more than mere techno-scientific disciplines. They are relevant for the functioning of societies, that is, operating the (local, regional, global) technosphere. The application of geoscience expertise in the daily dealings of societies deeply ties geosciences and people's social lives (Fressoz 2012; Bonneuil and Fressoz 2013; Purdy 2015). The Earth System (human niche) is a knotted patchwork of natural and cultural environments, the planetary social–ecological system. Human agency shapes it, regardless of whether the human agents are professional geoscientists, geoscientists acting as citizens, or citizens who pursue their personal, civic or professional activities. Therefore, people's socio-political practice matters, including, for example, the feedback between sense-making and acting, whether they act as individuals, groups or as agents in corporations or institutions. Culture, including ethical frameworks like geoethics, guides human agency. Tying geoethical thinking to the diverse human cultures is an (enormous) unsettled aspiration (Peppoloni and Di Capua 2020), although tying the globally hegemonic (Western) culture may be essential.

Promoting geoethical thinking as a feature of human cultures engages with societal sense-making, action and practices. In that context, geoethical thinking is a paradigm of the Earth System's functioning: the interplay of Nature and World. Given that (ambitious) context, geoethical thinking should inspire a much wider community than professional geoscientists; at least, that is an option (Bohle et al. 2019a, b). However, it is a challenge to promote geoethics throughout society, that is, making many reflecting *"on the values which underpin appropriate behaviours and practices, wherever human activities interact with the Earth system"* (Peppoloni and Di Capua 2015) (p. 4–5). As experiences show (Aragão 2021; Bohle et al. 2019a, b; Arroyo 2017), projecting guidance by experts or offering aspirational stipulations is constraint by socio-economic contexts. Therefore, a further extended framework that ties geoethical thinking in people's socio-economic lives and cultures is deemed necessary. The geo-ethical logic proposed in this essay is an intermediate step.

Geoscientists initially shaped geoethical thinking only for professional use. The four tenets of geoethical thinking (Table 2) describe how a geoscientist can act in a virtuous, responsible, and well-informed manner. These stipulations (virtuous, responsible, and well-informed) also appeal to people other than professional geoscientists. Hence, the design features of geoethical thinking provide a foundation to extend its use beyond the professional sphere of geoscientists (Di Capua et al. 2021). Searching for a methodology to describe the societal anchorage of geosciences (Marone and Bohle 2020) led to the political philosophies of Bunge (1989), Jonas (1981) and Kohlberg (1981). Two initial features could be added. First, the agency concept used in geoethical thinking could be generalised, namely considering individual, collective, corporate, and institutional human agents. As crucial as the individual is, human agency in the socio-political sphere is much more varied. Second, the limitations to the knowledge-base, mainly geoscience knowledge, can be dropped in favour of a broad base of reproducible knowledge, e.g. obtained by scientific methods. In this context, the knowledge-base geosciences

take a prominent place because of their essential contribution to understanding the Earth System. However, the human agent needs the entire corpus of scientific, reproducible knowledge to maintain a sustainable human niche.

Geoethical thinking does not prescribe what '*you-ought-to-do'* versus what '*you-ought-not-to-do'*, except that the knowledge-base is solely scientific. This essential feature of geoethical thinking renders its practices inclusive; hence, giving the plasticity needed in a highly diverse world. The (virtuous, responsible, knowledgeable) human agent is empowered to decide what normative framework shall be used in given circumstances. However, this pluralism (of ethical frameworks) gives much lee-wave when the application of geoethics is outside professional geosciences because of the additional framing by the professional norms of science and research (scientific culture and deontological codes) do not apply.

Whilst human agents other than scientists may meet the tenets of geoethical thinking, the tacit constraint of the scientific culture and the professional codes do not apply to them. Subsequently, the pluralism of geoethical thinking seems to be a design-risk (of decision overload) when geoethical thinking is applied outside the scientific sphere. To mitigate this risk, additional systemic socio-political benchmarking of geoethical thinking deems necessary, which depend on the anchorage of geosciences in people's social lives.

Applying the political philosophy of Bunge, Jonas and Kohlberg lead to explicit benchmarking, which is serving two purposes. First, they constrain pluralism and aspirational stipulations of geoethical thinking. Second, they tie geoethical thinking explicitly to people's social, political and cultural lives. However, an explicit tie with people's economic lives is still missing. However, it seems feasible to design such a tie using the political philosophy of Hannah Arendt (Arendt 1958).

Concluding, the present study proposes three socio-political benchmarks for applying geoethical thinking: (i) Kohlberg's *'hierarchy of societal coordination (moral adequacy)'*, (ii) Bunge's *'balance of happiness (well-being) and duty (for the individual)'*, and (iii) Jonas' *'imperative of responsibility (for agents of change)*'. Together they buttress geoethical thinking for an application outside the sphere of professional geosciences. Whilst also preserving the design of geoethics, they lead to a geo-ethical logic of six tenets, namely, calling for a practice of acting with agent-centricity, virtue-focus, responsible-focus, reproducible/scientific knowledge, all-agent-inclusiveness and universal-rights-base (Table 3). Admittedly, although simple, the geo-ethical logic is conceptual and, therefore, studies must be undertaken to apply it to given circumstances. For example, likely, the debate would vanish whether (Bohle and Bilham 2019), given the *'geoethical promise'* (Table 1), to amend the geological time scale by adding the Anthropocene at its end.

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