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Geoethics as a normative foundation for geoheritage, geoconservation, and geoeducation: from geological value toward moral responsibility

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Abstract

Geoethics provides the normative foundation for moving beyond valuation alone, reframing geoheritage as a moral reference point that grounds obligations of care, responsibility, and justice in human-Earth relations. While prevailing approaches emphasize the intrinsic, instrumental, aesthetic, scientific, or cultural value of geological features, value-based rationales by themselves do not fully explain why societies ought to care in the Anthropocene or how responsibilities emerge from human-Earth interactions. Grounded in contemporary geoethical theory, we propose an integrative framework that links geoscientific knowledge, ethical reasoning, and socio-cultural values, and that positions geoconservation and geoeducation as complementary ethical practices enacted within UNESCO Global Geoparks, other protected or designated socio-ecological contexts, and everyday landscapes beyond them. In this framing, geoconservation is reconceptualized as stewardship guided by equity (including intergenerational and interregional justice), precaution, and participatory governance. Geoeducation is articulated as a practice that, at its best, couples technical learning with ethical reflection, cultivating sense of place, moral sensibility, and agency through experiential, place-based, and community-engaged approaches. The framework is explicitly dynamic, emphasizing feedback loops through which learning supports conservation and conservation practice becomes a locus for learning and deliberation about competing values and trade-offs. The paper concludes

with implications for policy and governance and outlines empirical pathways for examining geoethical awareness across geocultural contexts, including within geopark networks and broader geoconservation initiatives.

Keywords: Geoethics, Geoheritage, Geoconservation, Geoeducation, Geodiversity, Anthropocene, UNESCO Global Geopark.

1. Introduction

This concept paper advances the argument that geoethics provides the normative foundation necessary to transform geological value into moral responsibility. Building on contemporary developments in geoethical theory and insights derived from geoeducation and geopark practice, it proposes moving beyond predominantly instrumental or purely descriptive approaches to geoheritage by situating them within an explicitly ethical framework. This does not negate the importance of value-based perspectives (scientific, cultural, educational, aesthetic, or economic); rather, it argues that such valuations are most robust and equitable when grounded in an explicit geoethical account of responsibilities and obligations. Within this framework, geoconservation and geoeducation are understood not only as technical or pedagogical activities, but also as ethical practices grounded in responsibility, care, intergenerational, and interregional (intragenerational) justice. By articulating this normative linkage, the paper contributes to ongoing debates on human-Earth relations and offers a coherent conceptual basis for future research, policy, and practice.

Earth functions as a complex and dynamic system in which biotic and abiotic components jointly sustain biodiversity, geodiversity, and the life-support processes upon which human societies depend (Gray, 2018). In the Anthropocene, however, this systemic balance is increasingly destabilized (Crutzen and Stoermer, 2000; Rosol et al., 2017; Zalasiewicz et al., 2018). Recent global assessments indicate that seven of the nine planetary processes regulating Earth's stability and resilience have already been breached, with pressures continuing to intensify (PBScience, 2025). These developments underscore the urgency of rethinking how human societies understand, value, and interact with the Earth system (Bohle et al., 2019).

Geodiversity has attracted growing attention across a wide range of disciplines, alongside an expanding set of definitions, analytical approaches, and related conceptual developments (Stojilković and Gray, 2024; Scammacca and Bétard, 2026). In this paper, we use geodiversity in its broad descriptive sense: the variety and variability of Earth's abiotic materials, forms, and processes, whether considered at the planetary scale or within a defined area (Zwolinski, 2004). This includes minerals, rocks, sediments, fossils, soils, and hydrological features (Gray, 2013; Brilha, 2016), as well as geological structures and geomorphic expressions such as folds, faults, and landforms. Crucially, geodiversity also comprises the natural processes that generate and transform these elements (e.g., tectonism, sediment transport, soil formation), because abiotic diversity is continually produced and reshaped through dynamic Earth-system functioning. While many definitions emphasize predominantly natural features and processes (Gray, 2013), geodiversity is increasingly recognized as relevant to the Earth's Critical Zone and to the provision of ecosystem services (Fox et al., 2020). However, its limited integration into international conventions and monitoring frameworks may constrain efforts to mainstream abiotic nature within sustainability governance and Sustainable Development Goals implementation (Schrodt et al., 2019; Matthews et al., 2024).

Geological heritage (geoheritage) referes to those elements of geodiversity – features, sites, and active processes – understood and framed as significant in scientific, educational, cultural, or other societal terms, and therefore considered relevant to stewardship, interpretation, and management. Geoheritage – comprising rocks, minerals, fossils, landforms, and active geological processes – faces escalating threats from anthropogenic activities such as pollution, intensive agriculture, deforestation, urbanization, mineral extraction, and land-use change (Scoullos et al., 2008; Gordon, 2019; Peppoloni and Di Capua, 2022). Climate-related pressures, including global warming, extreme events, habitat degradation, and declining environmental quality, further exacerbate these risks (Krasny, 2020). While biodiversity loss has received sustained scientific and political attention, geodiversity and geoheritage remain comparatively marginalized, despite their foundational role in ecosystem functioning, cultural landscapes, and human well-being (Almeida and Vasconcelos, 2015; Brilha et al., 2018). At the same time, their wide relevance is reflected in the inherently multidisciplinary character of, geodiversity and geoheritage research, spanning the full range of the geosciences and extending into the humanities and applied domains through integrated, interdisciplinary approaches (Kubalíková et al., 2023).

Demographic and spatial transformations compound these challenges. Rapid population growth and accelerating urbanization – projected to encompass nearly 70% of humanity by 2050 – are reshaping land use, intensifying resource demand,

and amplifying environmental pressures (UN, 2019, 2022). Significantly, a large proportion of future urban development has yet to occur, presenting both a risk of further degradation and an opportunity to reorient development pathways toward sustainability (Fragkias et al., 2013). Yet such reorientation remains constrained by dominant economic models and governance structures that privilege short-term growth and technocratic solutions over ethical reflection, relational responsibility, and long-term planetary stewardship (Huckle, 2009; Latour et al., 2018).

Within conservation discourse, this tension is reflected in the longstanding prioritization of biological diversity over geological diversity. Although biodiversity protection is indispensable, the neglect of geodiversity has important consequences (UNESCO, 2023): soils, rocks, landforms, and geological processes underpin ecosystems, shape cultural identities, and connect societies across temporal and spatial scales (Stanley, 2004; Gordon et al., 2012). Without a comprehensive understanding of Earth-system functionality that explicitly includes its abiotic foundations, environmental policy risks remaining fragmented and insufficiently grounded in the realities of planetary change.

Calls to integrate geological considerations into sustainability thinking are not new. From early philosophical reflections on human-nature relations (Emerson, 2009; Leopold, 2020) to contemporary scholarship on geoheritage, geotourism, geoeducation, and geosystem services, researchers increasingly recognize that geological features are not passive substrates but active contributors to human history, identity, and development (Gray, 2011; Brilha et al., 2018; Crofts et al., 2020; Drinia et al., 2022, 2023; Gray et al., 2024; Koupatsiaris and Drinia, 2024a). Yet despite this growing recognition, a critical gap persists: geoheritage protection continues to be justified primarily through value-based arguments – scientific, aesthetic, cultural, or economic – without sufficiently addressing why societies ought to care or what ethical obligations arise from human-Earth interactions in the Anthropocene (Bohle and Bilham, 2019).

This gap reveals a deeper problem of ethical foundationalism. Valuation alone, whether intrinsic or instrumental, is often insufficient to generate durable commitments to stewardship, particularly under conditions of competing interests, uncertainty, and intergenerational risk. What is required is a normative framework capable of translating geological significance into responsibility, governance, and action. Geoethics offers such a framework.

Geoethics has emerged as an interdisciplinary field concerned with the ethical, social, and cultural dimensions of human interactions with the Earth system, particularly within geoscientific practice (Peppoloni and Di Capua, 2012, 2021a). It seeks to clarify responsibilities, guide decision-making, and cultivate geoethical awareness across research, governance, education, and public engagement. Crucially, geoethics moves beyond descriptive accounts of environmental change toward normative

commitments grounded in responsibility, care, justice, and intergenerational equity (Bohle and Marone, 2021; Peppoloni and Di Capua, 2022).

Education plays a central role in operationalizing these commitments. Long-standing critiques of conventional education emphasize its tendency to fragment knowledge, detach learners from lived contexts, and separate cognition from emotion (Orr, 1992). In response, place-based and Earth-centred educational approaches have been advanced as means of reconnecting learners with their environments and fostering ethical agency (Orr, 1994; Sobel, 2004; Smith and Sobel, 2010; Vander Ark et al., 2020). Within this pedagogical landscape, geoeducation – and more specifically geoenvironmental education – provides a powerful avenue for integrating geoscientific understanding with ethical reflection and experiential learning (Koupatsiaris and Drinia, 2024a, 2025a).

UNESCO Global Geoparks exemplify this integrative potential. As territorially grounded initiatives that link geoheritage conservation, education, and sustainable development, UNESCO Global Geoparks function as living laboratories where scientific knowledge, community identity, and ethical practice intersect (Zouros and McKeever, 2008; Martini, 2009; Zouros, 2016; Gray, 2019; Nyulas et al., 2025). Through place-based education, participatory governance, and geotourism, geoparks cultivate sense of place, foster environmental citizenship, and embed geological heritage within everyday social and cultural life (Morgan, 2009; Larson et al., 2018; Santangelo and Valente, 2020).

Sense of place – encompassing emotional attachment and symbolic meaning – shapes how individuals perceive, value, and act toward their environments (Tuan, 1974; Relph, 1976; Ardoin, 2006; Kudryavtsev et al., 2012; Krasny, 2020). These affective and cognitive bonds provide motivational grounding for stewardship, responsibility, and care (Russ and Krasny, 2017; Ardoin et al., 2020). Within UNESCO Global Geoparks, other significant designated or protected socio-ecological areas, and beyond, place-based experiences allow geoheritage to be encountered not as abstract knowledge but as lived reality, thereby reinforcing the ethical dimensions of human-Earth relations (Koupatsiaris and Drinia, 2024b, 2025b).

At the societal level, these processes align with broader conceptions of environmental citizenship, which emphasize responsible action, civic participation, and recognition of environmental rights and duties across scales (ENEC, 2018; Jørgensen and Jørgensen, 2020). Contemporary formulations increasingly incorporate more-than-human perspectives and systems thinking, acknowledging the interconnectedness of human and non-human components within complex socio-ecological systems (Schill et al., 2019; Martínez-Martín et al., 2024). Geoethics complements and deepens this perspective by explicitly grounding citizenship in geoscientific knowledge and moral responsibility toward the Earth system (Peppoloni and Di Capua, 2023).

Against this backdrop, this concept paper advances a central claim: geoethics provides the normative foundation for reframing geoheritage from an object of value into a matter of moral obligation, and for positioning geoconservation and geoeducation as ethical practices through which these obligations are fulfilled. By framing geoheritage as a relational and meaning-laden component of the human-Earth interface, the paper moves beyond valuation alone toward responsibility, care, and justice (including intergenerational and interregional). It proposes an integrative conceptual framework in which geoethics provides normative coherence across valuation, stewardship, and learning, with UNESCO Global Geoparks serving as a key applied context for ethical enactment alongside other protected-area contexts and everyday landscapes.

The sections that follow develop this argument by (a) critically examining value-based approaches to geoheritage (Section 2); (b) establishing geoethics as a normative foundation for moral responsibility (Section 3); (c) reconceptualizing geoconservation and geoeducation as ethical practices (Section 4); (d) presenting an integrative conceptual framework (Section 5); and (e) outlining implications and directions for future research (Section 6).

2. Geoheritage beyond value

Moving beyond valuation alone requires recognizing geoheritage as a fundamentally relational construct. Geological features do not acquire significance solely through their material properties, scientific rarity, or aesthetic qualities, but through human perception, cultural interpretation, and lived experience. Landscapes, geosites, and geoparks are embedded within social narratives, collective memories, identities, and practices. From this perspective, geoheritage is not merely something to be valued, managed, or utilized; it is responsibility dimension of the human-Earth interface toward which people, communities, and institutions bear responsibilities. Such responsibility cannot be fully derived from valuation frameworks alone. It requires explicit normative grounding capable of guiding deliberation, governance, and action.

Traditionally, geoheritage has been conceptualized as the ensemble of geological features, landforms, and landscapes that document Earth's evolutionary history and possess scientific, educational, cultural, and aesthetic significance (GSA, 2011; Gordon et al., 2018). This understanding encompasses both in situ elements – geosites of high scientific relevance – and ex situ elements such as minerals, fossils, and rocks preserved in museum collections that retain interpretive and research value despite their displacement (Brilha, 2016). These definitions have provided

a robust foundation for identifying, classifying, and managing geological features of importance at local, national, and international scales (Gray, 2008, 2011, 2013). Beyond scientific relevance, geoheritage has long been recognized for its educational, cultural, and socio-economic functions. It supports formal and informal learning, underpins geotourism, and contributes to cultural identity and regional development (Carcavilla et al., 2009; GSA, 2011). The diversity of geoheritage expressions – geomorphological, petrological, mineralogical, palaeontological, stratigraphic, structural, hydrogeological, and pedological – illustrates the multiple ways in which Earth's history becomes legible and meaningful to society (Brilha, 2016). International initiatives, including UNESCO's early reports on geological heritage in 1999, the European Manifesto on Earth Heritage and Geodiversity in 2004, and the work of the International Union of Geological Sciences through the International Commission on Geoheritage (IUGS, 2022, 2024), have further reinforced the need to safeguard geological features for scientific, didactic, historical, and cultural reasons.

Over time, geoheritage discourse has expanded beyond isolated geosites to include culturally meaningful landscapes and territories where geological, biological, and human histories intersect (Brocx and Semeniuk, 2007; Pijet-Migoń and Migoń, 2022). This evolution reflects a broader shift within conservation thinking – from protectionist models that excluded human presence toward integrated approaches that recognize ecosystems and landscapes as socio-ecological systems shaped by long-term human-Earth interactions (Larwood et al., 2013; Vasconcelos and Orion, 2021). Within this framework, geoscientific knowledge is increasingly embedded in land- and resource-management decisions, and sites are categorized by levels of geosignificance to inform governance and planning (Brocx and Semeniuk, 2007; Brilha et al., 2018; GSA, 2024).

Despite this conceptual expansion, prevailing approaches to geoheritage remain largely value-based. Geological features are commonly justified for protection because they are rare, representative, aesthetically appealing, scientifically important, economically beneficial, or culturally symbolic (Gray, 2011). While such rationales are necessary, they are not always sufficient in the context of the Anthropocene (Ruban, 2020). Value-based reasoning alone struggles to explain why societies ought to protect geoheritage when short-term economic interests, extractive pressures, or infrastructural development present competing incentives. Nor does it adequately address questions of responsibility, justice, or obligation in the face of irreversible geological loss.

This limitation becomes particularly evident when geoheritage is framed primarily as an object of valuation – something to be assessed, ranked, and managed – rather than as a relational entity embedded in human histories, identities, and futures and therefore implicated in questions of responsibility and justice. Geological features

are not passive backdrops to human activity; they shape settlement patterns, resource use, cultural meanings, risk exposure, and collective memory over deep time (Dowling, 2011; Prosser, 2013). Former mining landscapes, sacred mountains, fossil-bearing terrains, and coastal landforms exemplify how geoheritage is inseparable from human civilization and socio-cultural evolution (Carcavilla et al., 2009).

Recent scholarship increasingly reframes geoheritage as a heritage asset whose significance extends beyond instrumental or intrinsic value toward its role in shaping human-Earth relationships (Newsome and Dowling, 2010; Ruban, 2015; Brilha et al., 2018; Brocx and Semeniuk, 2019; Vasconcelos and Orion, 2021). Within this perspective, geoheritage becomes a medium through which societies encounter deep time, environmental limits, and the consequences of human action. Such encounters inevitably raise ethical questions that valuation frameworks alone cannot resolve: Who bears responsibility for geological degradation? How competing uses of geological resources should be adjudicated? What obligations exist toward future generations in the face of irreversible geological change?

UNESCO Global Geoparks exemplify both the strengths and the limitations of value-based geoheritage frameworks. By integrating conservation, geoeducation, and sustainable development, geoparks have succeeded in elevating public awareness of geological heritage and its connections to culture and community identity (Zouros and McKeever, 2008; Gray, 2019; Koupatsiaris and Drinia, 2023, 2025c). Through geotourism, interpretation, and place-based learning, they mobilize tangible and intangible assets to foster local pride, scientific literacy, and economic opportunity (Martini, 2009; Fassoulas and Zouros, 2010; Martini et al., 2022). Research conducted within UNESCO Global Geoparks has advanced geoscientific knowledge while supporting broader sustainability goals (Zouros, 2007; Zouros and Valiakos, 2017; Orion, 2017; Ferreira and Valdati, 2023; Pérez-Romero et al., 2023).

Yet even within geoparks, geoheritage is frequently justified primarily through its utility – as a resource for education, tourism, or development – rather than through an explicit articulation of moral responsibility. In the Anthropocene, where human activity has become a dominant geological force, this omission becomes increasingly problematic (Rosol et al., 2017). Geodiversity helps underpin biodiversity, climate adaptation, and sustainable resource management, yet it remains underrepresented in sustainability discourse and policy frameworks (UNESCO, 2025). Protecting geoheritage, therefore, cannot rest solely on its usefulness or attractiveness; it requires a normative grounding that frames geological heritage as something to which societies owe care, restraint, and stewardship.

This emerging understanding marks a conceptual threshold: geoheritage must be approached not only through valuation, but also through moral significance, with each perspective strengthening the other. Valuation helps articulate what is at

stake (scientifically, culturally, educationally, aesthetically, and economically), while geoethical obligations specify what ought to follow from that significance in terms of responsibility, governance, and action. Geoethics is therefore indispensable – not as an add-on, but as the normative foundation that links geoheritage protection, geoconservation practice, and geoeducation to duties of care and justice (intergenerational and interregional) and to the fair balancing of competing values and perspectives.

Despite growing recognition of geoheritage as a scientific and cultural asset, the absence of a clearly articulated normative foundation continues to leave geoconservation vulnerable to competing economic, political, and technocratic priorities. Addressing this vulnerability requires a systematic ethical reframing – one that moves decisively beyond geological value alone toward moral responsibility.

3. Geoethics as normative ground

From a geoethical perspective, geoheritage is not merely an object of appreciation, valuation, or regulated use; it constitutes a moral reference point within human-Earth relations (Quesada-Valverde and Quesada-Román, 2023). The preservation of geosites, the sustainable use of georesources, and the communication of geological knowledge become ethical acts insofar as they shape impacts on present and future communities, ecosystems, and the resilience of the Earth system itself. Geoethics thus reframes geoheritage as a shared legacy that grounds obligations for human individuals and institutions – obligations owed not only to immediate stakeholders, but also to future generations and to the integrity of the non-human Earth system (e.g., ecosystems, species, and the abiotic processes that sustain them). Because ethical judgments are shaped by cultural, spatial, and temporal contexts, geoethics is particularly well suited to the diverse settings in which geoheritage is encountered – from local landscapes and communities to transnational geopark networks.

Geoethics has emerged as a rapidly developing field within applied ethics that examines the relationships between human activities and the Earth system, with particular emphasis on geoscientific knowledge and practice (Peppoloni and Di Capua, 2012). The International Association for Promoting Geoethics (IAPG) defines geoethics as "research and reflection on the values which underpin appropriate behaviours and practices, wherever human activities interact with the Earth system" (Peppoloni and Di Capua, 2021a). This definition positions geoethics not merely as a professional code for geoscientists, but as a broader normative framework concerned with the social, cultural, political, and ecological implications of how

societies understand, value, relate to, and interact with the Earth system, and how they use and govern its materials, processes, and places.

At its core, geoethics integrates ethical reflection with geoscientific knowledge across research, education, communication, governance, and decision-making contexts in which human actions affect geological processes, resources, and landscapes (Di Capua and Peppoloni, 2019). Drawing on philosophical, political, sociological, economic, and geoscientific traditions, geoethics offers an explicitly interdisciplinary framework capable of addressing complex, multi-scalar challenges – from climate change and geohazards to georesource management and territorial planning (Di Capua and Peppoloni, 2023).

Contemporary geoethics is both universal and pluralist. It articulates a shared ethical horizon grounded in human responsibility toward the Earth system while respecting cultural diversity, multiple epistemologies, and context-specific modes of action. Rather than prescribing a single moral doctrine, geoethics establishes a normative space within which societies can negotiate ethical commitments compatible with the dignity of human communities and with respect for the integrity of non-human components of the Earth system. This normative space cans also accomodate – and helps to weigh – value-based, instrumental, and transactional perspectives, without being limited to them. In this sense, geoethics embodies ecological humanism: a perspective that affirms human agency and responsibility without legitimizing domination over nature (Peppoloni and Di Capua, 2023).

Geoethics operates simultaneously at local, regional, and global scales, addressing both situated environmental decisions and planetary-level responsibilities. It is inherently pedagogical, aiming to cultivate ethical awareness, reflexivity, and moral agency rather than reinforcing technocratic control or extractive rationality (Bobrowsky et al., 2017). At the same time, geoethics is unavoidably political, insofar as it critiques materialism, consumerism, and short-term economic reasoning while advocating for equitable access to geoscientific knowledge, transparency, and inclusive deliberative processes – so that affected communities and stakeholders can participate meaningfully in decisions that shape their environments and futures.

From a normative standpoint, geoethics promotes the humane and responsible application of geoscientific knowledge for societal benefit while safeguarding Earth's geological heritage for present and future generations (Bohle and Marone, 2021). Peppoloni and Di Capua (2021a) identify four defining characteristics of geoethics: it is (a) human-agent centric, (b) structured as a form of virtue ethics, (c) grounded in geoscientific knowledge, and (d) implemented through space-time-context-dependent approaches. These characteristics frame humans as moral agents whose decisions must be evaluated not only in terms of efficiency

or utility, but also in terms of justice, responsibility, and respect for geodiversity, biodiversity and socio-ecological systems.

Within this framework, geoethical decision-making emerges from responsible autonomy – the capacity to act freely through informed and reflective judgment rather than coercion, habit, or purely instrumental reasoning (Peppoloni and Di Capua, 2020). Human agents operate within interconnected natural, social, cultural, and institutional domains, where ethical choices shape both environmental outcomes and social relations. Shared geoethical values guide action toward what is socially acceptable, ecologically sustainable, and morally defensible, enabling societies to navigate the complexity of human-Earth interactions with humility and care.

The scope of geoethics has been articulated through a set of foundational themes that delineate its theoretical and practical concerns. Peppoloni and Di Capua (2012) identify key geoethical themes, including the rational use of georesources, transparent scientific communication, emergency management, public engagement, respect for legal frameworks, interdisciplinary collaboration, and the development of effective educational tools. Collectively, these themes underscore that geoethics is not confined to abstract moral reflection but is explicitly oriented toward guiding real-world practices across science, policy, and education.

Geoethics is therefore intrinsically linked to sustainability. As defined by the Brundtland Report, sustainable development entails meeting present needs without compromising the ability of future generations to meet their own (WCED, 1987). Because environmental ethics concerns the moral evaluation of human behaviour in relation to the natural world (McShane, 2009), geoethics provides a domain-specific articulation of sustainability principles as they pertain to the Earth system. Issues such as georesource exploitation, georisk governance, climate research, ocean science, and socio-ecological transformation all carry ethical implications that cannot be resolved through technical expertise alone.

In this context, geoethical thinking – the application of ethical principles to geoscientific decision-making (Bohle, 2018) – becomes indispensable. Geoethical awareness can help operationalize this thinking by translating abstract values into practical orientations that guide decisions toward sustainability, equity, and ecological integrity (Peppoloni et al., 2019; Chan and Mogk, 2023). Insofar as it is taken up in practice, it seeks to align human activities with planetary boundaries, support efforts to safeguard planetary health, and reframe geological and cultural heritage as domains of shared responsibility (Peppoloni and Di Capua, 2016, 2021a, 2024). The Cape Town Statement on Geoethics (Di Capua et al., 2017) formalizes this normative orientation by articulating shared reference values, including honesty, integrity, transparency, competence, cooperation, respect for natural processes, protection of geodiversity, enhancement of geoheritage, sustainability of economic

activities, and the promotion of geoeducation for all. These values integrate individual virtues, social responsibilities, and cultural commitments, forming a coherent ethical framework for sustainable development (Antić et al., 2020).

Importantly, geoethics occupies a distinctive position within environmental ethics. While it is epistemically anthropocentric – grounded in human knowledge and responsibility – it need not be morally anthropocentric (Peppoloni and Di Capua, 2021b). Contemporary debates explore its compatibility with ecocentric and relational perspectives, suggesting that geoethics can function as a unifying ethical framework capable of accommodating diverse moral standpoints (Kopnina et al., 2018; Frigo and Ifanger, 2021). In doing so, geoethics bridges environmental virtue ethics, public ethics, and global ethics, situating human responsibility within a more-than-human Earth system (Di Capua et al., 2021; Frigo et al., 2024).

Within geoeducation, geoethics can nurture ethical awareness, values, and a sense of responsibility by integrating cognitive and affective dimensions of learning (Peppoloni and Di Capua, 2015; Bohle and Marone, 2021). Introducing geoethical principles to students and early-career professionals establishes foundational moral reference points that can guide future practice. Because geoscience is inherently action-oriented, these values must be continuously contextualized and validated through concrete outcomes in conservation, governance, and education (Peppoloni and Di Capua, 2020; Di Capua et al., 2021; Koupatsiaris and Drinia, 2025d, 2025e).

Taken together, geoethics provides the normative ground required to move beyond geological description and valuation alone toward moral responsibility. It reframes geoheritage from an object of valuation into a locus of ethical concern and positions geoconservation and geoeducation as practices through which societies enact responsibility, justice, and care toward the Earth system.

4. Geoconservation and geoeducation as ethical practices

If geoethics provides the normative ground that reframes geoheritage from an object of value into a matter of moral obligation, then geoconservation and geoeducation constitute the primary ethical practices through which this obligation is fulfilled. Viewed through a geoethical lens, neither geoconservation nor geoeducation can be understood as neutral or purely technical activities. Geoconservation involves normative choices concerning what is protected, how competing land uses are negotiated, and whose values, interests, and futures are prioritized. Geoeducation, in turn, operates as a principal mechanism through which geoethical awareness is cultivated, transmitted, and sustained across generations.

Geosciences occupy a central position in contemporary discussions of human, social, and natural capital because they provide the knowledge base required to understand Earth systems, manage resources, and anticipate environmental risks (Peppoloni and Di Capua, 2012). Within the broader framework of environmental literacy, geosciences encompass the study of interactions among biotic and abiotic systems, the impacts of human activities on nature, the forecasting of hazardous phenomena, and the sustainable management of critical resources such as energy, water, soils, and minerals (AGI, 2012; Orion, 2017; GSA, 2024). Geoscientific knowledge is therefore indispensable for addressing major global challenges, including climate change, biodiversity loss, and increasing exposure to natural hazards.

This centrality is reflected in recent analyses indicating that approximately 23% of geoscience publications contribute directly to 16 of the 17 United Nations Sustainable Development Goals, with particularly strong representation in Sustainable Cities and Communities (SDG 11), Climate Action (SDG 13), Life Below Water (SDG 14), and Clean Water and Sanitation (SDG 6) (McMellon, 2023). These findings confirm that geoscience is not merely adjacent to sustainability agendas but structurally necessary for their realization (Gill, 2017, 2021).

Within this geoscientific landscape, geoconservation has emerged as a distinct field dedicated to the protection and wise use of geodiversity for its scientific, educational, cultural, and heritage values (Sharples, 2002; Henriques et al., 2011; Gordon, 2019). It encompasses the identification, safeguarding, and management of geological features – including rocks, minerals, fossils, landforms, and active geological processes – while explicitly recognizing their interdependence with biodiversity and ecosystem services (Larwood et al., 2013; Crofts, 2014). Because biodiversity is underpinned by geodiversity, effective conservation requires the integration of bioconservation and geoconservation within a unified environmental framework (Sharples, 2002; Brocx and Semeniuk, 2007).

Although geoconservation developed relatively recently as a formal scientific field, its emergence reflects growing recognition that geological features are vulnerable to degradation and irreversible loss, and that their preservation is essential for both present and future generations (Prosser et al., 2011). From a geoethical perspective, geoconservation cannot be reduced to a technical or managerial exercise. Rather, it constitutes a form of ethical stewardship grounded in responsibility toward the Earth system and in obligations of intergenerational and interregional (intragenerational) justice. Decisions regarding extraction, land transformation, hazard mitigation, or site protection are inherently ethical, as they shape environmental trajectories, social vulnerability, and the distribution of risks and benefits across time and across places, often in ways that reflect wider disparities in wealth, governance capacity, and power.

This ethical orientation is articulated through core geoethical commitments and guiding values – geoheritage, geoconservation, sustainability, adaptability, risk prevention, and geoenvironmental education – which collectively reinforce the human-Earth relationship by fostering care, belonging, and stewardship (Peppoloni and Di Capua, 2022; Antić et al., 2026). These values emphasize respect for natural processes, soil integrity, and the health and safety of human communities, situating geoconservation within a broader normative framework of environmental responsibility (Di Capua and Peppoloni, 2019). In this sense, geoconservation is not only about conserving objects, but also about acting responsibly within socio-ecological systems shaped by human agency.

Geoeducation constitutes the complementary practice through which geoconservation-related meanings and commitments are communicated, internalized, and enacted within society. It has been defined as the teaching and learning process – across formal, non-formal, and informal contexts – that integrates geological knowledge with the natural and cultural elements of place (Fernández Álvarez, 2020; Ferdowsi et al., 2025). Geoeducation therefore serves not only as a vehicle for transmitting geoscientific knowledge and building practical competencies, but also as a geoethically informed pedagogical space that cultivates understanding of Earth-system dynamics, fosters critical reflection on human-Earth interactions, and supports responsible participation in environmental decision-making. Crucially, embedding geoeducation within a geoethical framework does not diminish its instrumental aims (e.g., literacy, capacity-building, risk awareness, stewardship); rather, it strengthens them by making underlying values explicit and orienting learning toward more just and sustainable outcomes.

The concept of geoliteracy provides a foundational educational framework, emphasizing systems thinking, interconnectedness, and the ability to apply geoscientific knowledge to real-world challenges (Edelson, 2014). Building on this foundation, Henriques et al. (2011) distinguish education about, in/by, and for geoconservation – paralleling Lucas's (1972) typology in environmental education. These dimensions highlight that geoeducation simultaneously develops conceptual understanding, experiential engagement, and ethical agency oriented toward conservation action.

Crucially, geoeducation is not value-neutral. It carries an ethical dimension insofar as it invites learners to reflect on questions of responsibility, fairness, appropriateness, and acceptability in relation to environmental decisions (Peppoloni and Di Capua, 2022). At its best, through experiential learning, place-based education, and community engagement, geoeducation can nurture affective connections to place and support the internalization of geoethical orientations. However, these ethical dimensions are not always made explicit in practice. When geoeducation is framed as "purely

technical," its underlying values may remain implicit rather than absent – leaving learners less able to recognize, critically examine, and negotiate the normative assumptions shaping geoscientific knowledge and environmental decision-making. In this sense, geoethically informed geoeducation should function as a process of ethical formation, shaping how individuals and communities perceive and assume responsibility toward geoheritage and the Earth system more broadly.

UNESCO Global Geoparks provide an exemplary applied context in which geoconservation and geoeducation converge as ethical practices. UNESCO Global Geoparks pursue three interrelated objectives: the conservation of geoheritage, the dissemination of geoscientific education, and the promotion of sustainable economic development – primarily through geotourism (Gray, 2019). Central to the geopark model is a bottom-up, community-centered approach that positions local populations not as passive beneficiaries but as active stewards of their geoheritage (UGGps, n.d.; UNESCO, n.d.). While geoparks are particularly visible arena for integration, analogous geoethical dynamics can also be pursued in other protected-area settings and in non-designated landscapes beyond geopark limitations.

By linking geological features with cultural identity, local knowledge, and educational initiatives, UNESCO Global Geoparks facilitate the translation of abstract geoethical principles into lived practice. As Gray (2013) notes, the aim is to enable communities to take ownership of their geological and cultural heritage by protecting and promoting it in ways that generate sustainable social and economic benefits (Ferreira and Valdati, 2023). Through guided interpretation, educational programs, and participatory governance, geoparks foster geoethical awareness among residents, visitors, and decision-makers alike (Koupatsiaris and Drinia, 2025d, 2025e).

At the same time, UNESCO Global Geoparks face persistent challenges. Insufficient awareness, environmental degradation, and overtourism threaten geosites and local communities, underscoring the need for management strategies explicitly grounded in ethical reasoning (Larwood et al., 2013; Gordon, 2019). Addressing these challenges requires viewing geoconservation and geoeducation not as ancillary or supportive functions, but as normative practices through which geoethical responsibility is enacted.

From this perspective, geoconservation represents ethical action aimed at safeguarding the material foundations of the Earth system, while geoeducation represents ethical formation – cultivating the knowledge, values, and dispositions necessary for responsible stewardship. Together, they operationalize geoethics by transforming moral commitments into sustained practices across science, education, governance, and community life.

5. An integrative geoethical conceptual framework

This concept paper advances an integrative conceptual framework in which geoethics functions as the normative core linking geoheritage, geoconservation, and geoeducation. The framework responds to a persistent limitation within geoheritage and geoconservation discourse: although geological features are increasingly acknowledged for their scientific, educational, aesthetic, ecological, and cultural value (Brocx and Semeniuk, 2007; De Miguel, 2021; Pescatore et al., 2023), value-based rationales alone are often insufficient to explain why societies ought to care in the Anthropocene or how ethical obligations emerge from human-Earth interactions (Peppoloni and Di Capua, 2022). Importantly, the framework does not displace valuation; it embeds value-based considerations within an explicit geoethical account of responsibilities and obligations, and of how competing values and perspectives can be weighed fairly.

By positioning geoethics as a normative foundation, the framework clarifies how recognition of geological value is translated into moral responsibility, and how this responsibility is enacted through ethical practices of stewardship and learning. In doing so, it provides conceptual coherence to fields that have often developed in parallel – geoheritage, geoconservation, and geoeducation – without an explicit shared ethical grounding.

At the base of the framework lies geoheritage, understood not merely as a collection of valuable geological features but as a relational and meaning-rich dimension of the human-Earth interface (Gray, 2013; Migoń, 2021; Pijet-Migoń and Migoń, 2022; Migoń and Pijet-Migoń, 2024). Geoheritage encompasses both in situ and ex situ elements of geodiversity that carry scientific, educational, cultural, and aesthetic significance (Brilha, 2016; Gordon et al., 2018), while simultaneously embodying historical memory, identity, and intergenerational continuity.

Within this framework, geoheritage is reframed as a moral reference point rather than a passive object of valuation. Its significance is inseparable from responsibility, care, and justice – particularly in the Anthropocene, where human activity has become a dominant geological force (Crutzen and Stoermer, 2000; Zalasiewicz et al., 2018; Bohle and Bilham, 2019; Ruban, 2020). This reframing moves beyond instrumental or intrinsic valuation alone by coupling recognized values with responsibilities of care, restraint, and stewardship, especially given geoheritage's irreplaceability, its role in sustaining socio-ecological systems, and its deep entanglement with human histories and futures (Prosser, 2013; Brilha et al., 2018; Brocx and Semeniuk, 2019).

Geoethics provides the normative orientation that enables this transition from recognition of geological value to a matter of moral obligation. Defined as research and reflection on the values underpinning appropriate behaviours wherever

human activities interact with the Earth system (Peppoloni and Di Capua, 2021a), geoethics integrates geoscientific knowledge with ethical reasoning and socio-cultural values to guide responsible decision-making (Peppoloni and Di Capua, 2012; Di Capua and Peppoloni, 2023).

Within the proposed framework, geoethics functions as the ethical backbone articulating duties for human agents toward geoheritage through principles such as responsibility, care, justice, precaution, and intergenerational ethics (Peppoloni and Di Capua, 2021a, 2022). These principles do not reject anthropocentrism; rather, they reconfigure it into a responsible anthropocentrism that recognizes human agency while affirming moral obligations toward the broader Earth system (Peppoloni et al., 2019; Bohle and Marone, 2021).

Geoethics thus establishes the crucial transition from descriptive recognition – what geoheritage is worth (and to whom) – to normative commitment – what ought to be done. It provides ethical justification for conservation choices under conditions of uncertainty, competing interests, and socio-economic pressures that characterize the Anthropocene (Vasconcelos et al., 2016; Di Capua et al., 2021).

Within this normative structure, geoconservation and geoeducation are conceptualized as ethical practices through which geoethical responsibility is operationalized.

Geoconservation is understood as ethical stewardship: the protection, management, and wise use of geodiversity guided by principles of responsibility, equity, precaution, and sustainability (including intergenerational and interregional justice) (Sharples, 2002; Henriques et al., 2011; Gordon, 2019). It entails governance decisions that balance protection with sustainable development, integrate geoscientific knowledge into land-use planning, and address geohazards, resource use, and long-term resilience (Prosser et al., 2011; GSA, 2024). In this sense, geoconservation is not value-neutral but normatively charged, expressing societal commitments toward both present and future generations.

Geoeducation, in turn, is articulated as a transformative ethical practice that cultivates awareness, values, and agency. Through place-based education, experiential learning, and community engagement, geoeducation fosters emotional and cognitive connections to place, strengthens sense of place, and supports the internalization of geoethical values (Rokka, 2001; Krasny, 2020; Koupatsiaris and Drinia, 2024a). By integrating scientific understanding with affective and moral dimensions, geoeducation enables individuals and communities to relate to geoheritage not merely as information to be learned, but as a shared legacy that calls for care, responsibility, and stewardship (Peppoloni and Di Capua, 2015; Fornaro and Fernandes, 2018).

The framework is explicitly dynamic rather than linear. While geoethics provides the normative foundation, geoconservation and geoeducation interact through continuous

feedback loops. Geoeducation strengthens geoconservation by shaping public understanding, legitimizing protective policies, and encouraging participation. As individuals develop stronger place attachment and place meaning, they be more likely to support conservation measures and engage in stewardship practices (Koupatsiaris and Drinia, 2024b, 2025b). Conversely, ethically informed geoconservation actions – such as protected geosites, participatory governance arrangements, negotiated management plans, and sustainable geotourism – do more than reinforce educational messages: they provide a concrete setting in which learners and communities can observe, interpret, and critically reflect on how geoscientific knowledge and Earth processes intersect with social priorities, economic constraints, environmental trade-offs, and moral obligations. In this way, geoconservation sites and practices can function as real-world, context-dependent "laboratories" for demonstrating how competing perspectives and values are identified, debated, and navigated in a principled manner – making geoethical commitments actionable while also delivering geoheritage value in its scientific, educational, cultural, aesthetic, and socio-economic senses.

Geoethics permeates these interactions, offering a reflective and adaptive normative lens through which practices are evaluated, justified, and revised over time. In this sense, geoethics functions not as a static code but as an evolving ethical compass capable of responding to changing environmental, social, and institutional contexts (Peppoloni and Di Capua, 2022).

This integrative framework aligns closely with the mission of UNESCO Global Geoparks, which explicitly combine geoheritage conservation, geoeducation, and sustainable development (Gray, 2019). UNESCO Global Geoparks are conceptualized here not merely as protected areas, but as applied arenas of geoethical practice – territories where valuation, responsibility, stewardship, and learning are intentionally intertwined (Koupatsiaris, 2026). As a global network, geoparks also provide opportunities for cross-site learning, comparison, and dialoque across diverse social, environmental, and governance contexts.

By making the ethical dimension explicit, the framework clarifies the added value of geoparks as living laboratories for geoethics: spaces where geoheritage becomes morally meaningful, geoconservation is enacted as ethical stewardship, and geoeducation cultivates the sensibilities and agency required for responsible human-Earth relationships (Zouros, 2016; Martini et al., 2022; Koupatsiaris and Drinia, 2024b).

In summary, the proposed framework articulates a coherent normative logic (Figure 1). Geoethics is positioned as the normative foundation that transforms geoheritage from an object of value into a moral reference point. Geoheritage is understood as a relational, meaning-laden component of the human-Earth interface.

Geoethical principles – responsibility, care, justice, precaution, and intergenerational ethics – provide orientation, while geoconservation and geoeducation operate as complementary ethical practices that enact this responsibility. The framework is dynamic, with feedback loops through which education reinforces conservation and conservation practices strengthen educational meaning. UNESCO Global Geoparks are depicted as applied arenas where these interactions are operationalized across scales, not only within individual geoparks but also through the global network, which provides opportunities for cross-site learning, comparison, and dialogue about how geoethical principles can be interpreted and enacted under different social, environmental, and governance conditions.

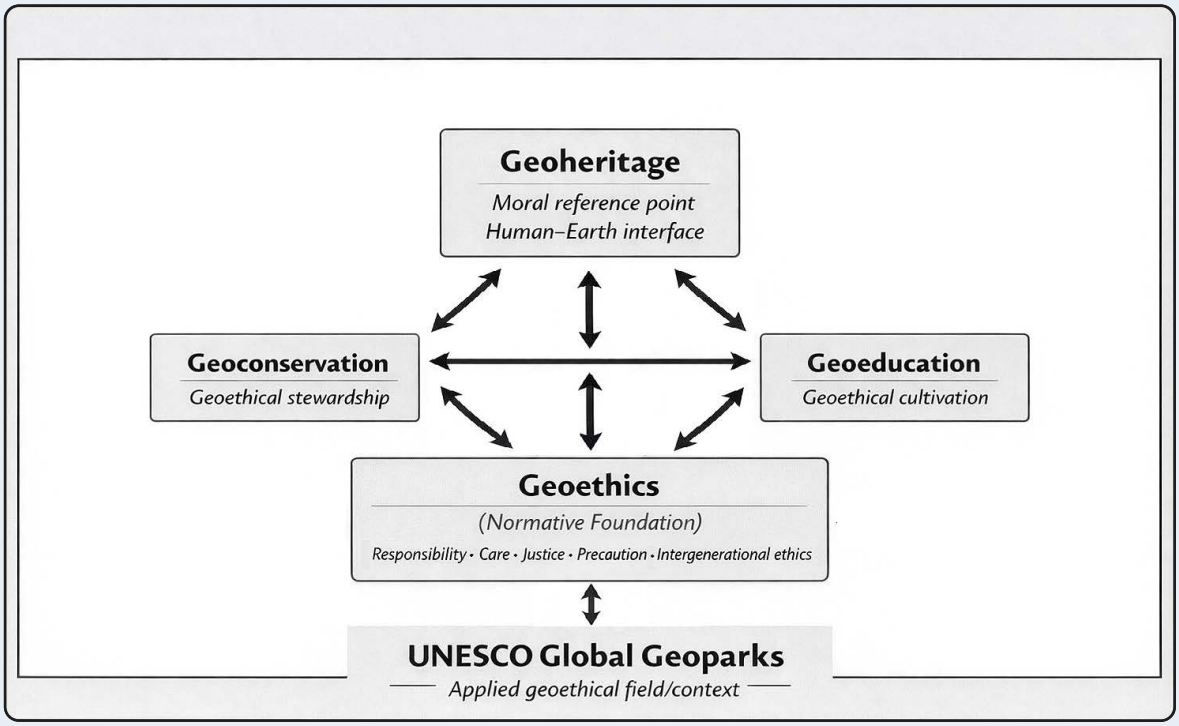

Figure 1. *An integrative geoethical framework positioning geoethics as the normative foundation linking geoheritage, geoconservation, and geoeducation, operationalized within UNESCO Global Geoparks and beyond as applied arenas of geoethical practice.*

6. Implications and future research: An avenue

Positioning geoethics as the normative foundation linking geoheritage, geoconservation, and geoeducation carries significant implications for theory, policy, practice, and research in the Anthropocene. Conceptually, this shift moves geoheritage discourse beyond descriptive classification and instrumental valuation alone toward a principled understanding of moral responsibility in human-Earth relations. Geoheritage is no longer framed merely as something valuable to be protected when convenient, but as a moral reference point that grounds obligations of care, justice, and intergenerational responsibility. This normative repositioning strengthens the theoretical coherence of geoheritage-related fields and clarifies why geoconservation and geoeducation are not optional or ancillary activities, but ethical practices through which responsibility can be enacted.

From a policy perspective, the proposed framework offers a normative lens through which environmental governance and geocultural heritage management can be reoriented. Integrating geoethical principles into decision-making processes can enhance the legitimacy, inclusiveness, and long-term robustness of policies governing georesource use, climate adaptation, risk management, and geoconservation. This does not displace value-based approaches (economic, scientific, cultural, educational, aesthetic), but provides an explicit ethical grounding for how such values are identified, justified, negotiated, and balanced across stakeholders and over time. Accordingly, rather than relying solely on economic valuation, technical optimization, or regulatory compliance, geoethics foregrounds responsibility, precaution, equity, and care as guiding principles for governance under conditions of uncertainty and competing interests.

Within this perspective, UNESCO Global Geoparks emerge not simply as administrative designations or conservation instruments, but as ethical infrastructures. Their explicit integration of conservation, education, and sustainable development positions them as living laboratories for testing and refining participatory governance models that align scientific evidence with ethical imperatives and local priorities. In addition, the global geopark networks provide opportunities to reflect on how geoethical principles can be interpreted and enacted under different constraints and aspirations. The framework highlights the importance of culturally sensitive, accessible, and community-driven outreach as a mechanism for diffusing geoethical orientations and broadening the social base of support for conservation and resilience, both within geoparks and beyond their boundaries.

Reconceptualizing geoconservation as an ethical practice emphasizes stewardship as a form of moral agency rather than technical management alone. Decisions concerning site protection, tourism development, risk mitigation, and resource use

are framed as ethical choices made under conditions of uncertainty and unequal impacts, with intergenerational and interregional (intragenerational) consequences. This perspective underscores the responsibility of geoscientists, managers, and institutions to act transparently, inclusively, and reflexively when shaping interventions in socio-ecological systems, and to scrutinize how "context-specific" standards may normalize unequal burdens or uneven protections across regions and communities. Geoeducation, within the proposed framework, functions as a transformative process through which geoethical responsibility can be cultivated and sustained. Place-based, experiential, and action-oriented pedagogies play a central role in fostering sense of place, moral sensibility, and agency among learners. Emotional and cognitive connections to landscapes – developed through direct experience, interpretation, and participation – are not ancillary outcomes but core ethical capacities that can enable individuals and communities to translate knowledge into pro-environmental and pro-social behaviour (Grilli and Curtis, 2021; Bohle and Marone, 2022). Standardized yet adaptable educational frameworks that embed these experiential dimensions can help counter fragmented and extractive practices while supporting more resilient human-Earth relationships.

The framework advanced in this paper is intentionally generative and invites systematic empirical investigation. Future research should examine how geoethical awareness develops across different social, cultural, and geographic contexts, and how it mediates the relationships among geoeducation, sense of place, and environmentally responsible behaviour. Longitudinal research designs are particularly needed to move beyond short-term assessments and to trace the durability, trajectories, and transformative potential of geoethical orientations over time.

Interdisciplinary and mixed-method approaches – integrating quantitative measures with qualitative methods such as interviews, focus groups, ethnography, and participant observation – can clarify not only whether ethical shifts occur, but how and why they are sustained. Experimental and quasi-experimental evaluations of educational interventions, including experiential learning, service learning, citizen-science initiatives, and place-based curricula, can further identify which pedagogical elements most effectively cultivate geoethical reasoning and stewardship. Comparative research across multiple UNESCO Global Geoparks, other protected or designated areas, and geoenvironmental sites is essential for distinguishing broadly transferable ethical patterns from place-specific dynamics. Attention to linguistic, cultural, and contextual diversity will illuminate how local narratives, histories, worldviews, and governance conditions shape ethical engagement. Methodologically, the continued development, validation, and cross-cultural refinement of instruments designed to assess geoethical awareness can support evidence-based evaluation of educational and conservation initiatives. Longitudinal and repeated-measures

designs, combined with multilevel modelling, can help disentangle individual-, community-, and site-level influences on ethical orientations.

Beyond individual studies, the framework encourages closer dialogue between geosciences, ethics, education, and the social sciences. By conceptualizing geoheritage, geoconservation, and geoeducation as interconnected ethical practices, geoethics can function as a unifying paradigm that enhances both scholarly coherence and societal relevance. Strengthening links between research, policy, and practice will enable educational institutions, geopark authorities, and local governments to design targeted, inclusive, and context-sensitive strategies for engagement, capacity building, and resource allocation.

Aligning future research and implementation with the United Nations Sustainable Development Goals – particularly SDG 4 (Quality Education), SDG 11 (Sustainable Cities and Communities), SDG 13 (Climate Action), SDG 14 (Life Below Water), SDG 15 (Life on Land), SDG 16 (Peace, Justice, and Strong Institutions), and SDG 17 (Partnerships for the Goals) – further situates geoethical practice within global sustainability agendas. To support evaluation, geoenvironmental engagement profiles can be understood as documented patterns of participation and interaction: who is engaged, through which activities, with what frequency and intensity, and what degree of inclusion and decision-making influence. Linking such engagement profiles to independently verified ecological and socio-economic indicators can help assess tangible outcomes associated with geoethical interventions and enable comparison across contexts.

In an era of profound environmental transformation, moving beyond geological value alone toward moral responsibility is not optional but necessary. By positioning geoethics as the normative foundation of geoheritage-related practices, this concept paper offers a coherent ethical framework capable of guiding stewardship, education, and governance in the Anthropocene. Geoethics provides the conceptual bridge through which care for the Earth becomes reflective, place-based, and collectively negotiated – grounding sustainable and resilient futures in shared ethical commitments alongside, and not in place of, the multiple values of geoheritage.

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