

Article

Geological Processes in the Anthropocene Epoch

Bo'riboy Raxmanov¹, Jo'rakulov Xayrulla², Laziz Uralov³, Baxtiyor Meliev⁴, Marhabo Safarova⁵, Nurqobilov Doniyor⁶

1. Professor of Samarkand State University named after Sharof Rashidov
 2. Professor of Samarkand State University named after Sharof Rashidov
 3. Lecturer at Samarkand State University named after Sharof Rashidov
 4. Dotsent of Samarkand State University named after Sharof Rashidov
 5. Lecturer at Samarkand State University named after Sharof Rashidov
 6. Lecturer at Samarkand State University named after Sharof Rashidov
- * Correspondence: meliyevbaxtiyor27@gmail.com⁴

Abstract: This article examines the latest geological processes occurring on our planet and the resulting geological environment emerging from these activities. Even though the term "Anthropocene" is not taken seriously because of its importance for modernity and the future, scientists around the world are perplexed. It explores the significance of human impact on the Earth system and addresses whether it is possible to mitigate the various disasters currently unfolding or those that await in the future. Yes, to track geological processes and conduct research, human life is short, but we must leave more information for future generations. Through this comprehensive analysis, the study seeks to provide scientific answers to these critical questions.

Keywords: Anthropocene, Technosphere, Stratigraphy, Technofossils, Great Acceleration, Lithostatic Pressure

Introduction

Over the course of approximately 4.5 billion years, Earth has passed through numerous geological stages, each defined by natural processes such as volcanic activity, plate tectonics, and climatic fluctuations. However, the current phase of planetary evolution appears fundamentally different, not because natural forces have ceased to operate, but because a single species has begun to influence these systems at an unprecedented scale [1]. This realization has led to the emergence of the concept of the Anthropocene, a term used to describe a new stage in which human activity has become a dominant force shaping the Earth's climate, ecosystems, and geological structure [2]. The term was introduced into scientific discourse in 2000 by Paul Crutzen, who famously interrupted a discussion about the Holocene by asserting that humanity had already moved beyond it. Yet the intellectual foundation of this idea extends further back. In the nineteenth century, Antonio Stoppani suggested that humans had become a geological force, while in the twentieth century, Vladimir Vernadsky proposed that human reason would transform the biosphere into a "noosphere," where intellectual activity governs planetary processes. Today, these early insights have evolved into a robust scientific framework supported by empirical evidence [3, 4]. The scale of human presence alone is extraordinary. Estimates suggest that approximately 117–119 billion people have lived on Earth, and according to E. O. Wilson, human biomass now exceeds that of most large animal species combined. This shift indicates that humanity is no longer a passive component of the biosphere but an active

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geological agent capable of altering the Earth system at multiple levels [5]. At the same time, the Anthropocene is not defined by a single factor but by the convergence of multiple processes, including industrialization, technological innovation, population growth, and environmental transformation. These processes collectively form what scientists describe as a new planetary condition, one in which natural and artificial systems are deeply intertwined [6].

Methodology

To examine the Anthropocene as a scientifically grounded phenomenon, this study employs an interdisciplinary analytical approach that integrates geological, mineralogical, ecological, and climatological data. The goal is not merely to describe environmental change, but to identify measurable indicators that demonstrate how human activity is being recorded within the Earth's physical structure. A key methodological component involves stratigraphic analysis, which focuses on identifying markers within sedimentary layers that can define a distinct geological interval. This approach is based on the work of Jan Zalasiewicz, who emphasizes that every geological epoch must leave a clear and lasting signature in the rock record. By examining materials embedded in modern sediments, such as plastics, metals, and radioactive particles, it becomes possible to assess whether current changes meet this criterion. In addition to stratigraphy, mineralogical analysis is used to investigate the formation of new mineral species resulting from human activity. These minerals are studied in environments such as mines, industrial waste sites, and marine settings, where chemical interactions between human-made materials and natural elements produce entirely new crystalline structures. The study also incorporates ecological and atmospheric data to evaluate broader Earth system changes. Biodiversity loss, climate trends, and ocean chemistry are analyzed using global datasets, with particular attention given to the period known as the "Great Acceleration" beginning in the mid-twentieth century. This period is characterized by a rapid increase in population, industrial output, and environmental impact. Finally, regional case studies are used to illustrate the interaction between human activity and geodynamic processes. The Aral Sea basin is examined as a model system, providing insight into how large-scale environmental changes can influence lithospheric stability, hydrospheric balance, and even seismic activity.

Results

The analysis reveals that human activity has produced a wide range of measurable and persistent changes that are already being recorded in the Earth's geological and ecological systems. One of the most significant findings is the emergence of technofossils, which include materials such as concrete, aluminum, glass, and plastics [7]. These substances, once integrated into sedimentary layers, will remain as long-lasting markers of human presence. Even if modern cities collapse, their material remains will continue to exist within the geological record. Another key result is the global distribution of radioactive isotopes resulting from nuclear testing beginning in 1945, including events such as Hiroshima and Nagasaki. These isotopes provide a precise chronological marker that can be used to define the beginning of the Anthropocene in stratigraphic terms. Plastic pollution represents another major indicator [8]. Over time, plastic waste accumulating in oceans and soils is expected to form a distinct synthetic layer derived from petroleum-based materials. This layer will be unlike any natural sediment, clearly distinguishing the Anthropocene from previous epochs. A particularly unusual but scientifically important marker is the widespread presence of chicken bones. Industrial poultry farming has produced billions of genetically similar birds, whose remains are found in concentrations that do not occur naturally, making them a potential fossil indicator of human activity. The mineralogical impact of human activity is equally profound. More than 200 new mineral species have been identified as products of anthropogenic processes. These include minerals formed through corrosion, chemical reactions, and industrial waste interactions [9, 10].



Figure 1. Anthropogenic minerals formed as a result of human technological processes

Minerals: a synthesis of nature and technology

Examples include abhurite formed on submerged tin, chalconatronite developing on ancient bronze artifacts, andersonite crystallizing in uranium mines, neallite emerging from metallurgical waste, and simonkolleite forming in zinc-rich industrial environments. These minerals illustrate how human activity is actively reshaping geochemical processes. In addition to minerals, entirely new rock types have emerged. Plastiglomerate, formed by the fusion of melted plastic with natural materials, represents a new category of anthropogenic rock. Trinitite, created during nuclear explosions, contains radioactive elements and provides a precise temporal marker [11]. Corium, produced during nuclear reactor meltdowns such as Chernobyl, forms lava-like structures composed of fuel and structural materials. Fordite, although less hazardous, represents layered industrial paint deposits that have hardened over time. The impact of human activity is also evident in biodiversity loss. Current extinction rates are estimated to be up to 100–1000 times higher than natural background levels, indicating the onset of the sixth mass extinction. Insects, birds, and marine organisms are particularly affected. For instance, insect populations are declining rapidly, agricultural birds in Europe have decreased by hundreds of millions, and marine ecosystems are under threat due to ocean acidification [12]. Climate data further support these findings. Carbon dioxide levels have increased dramatically since the Industrial Revolution, particularly during the Great Acceleration period after the 1950s. This has led to rising global temperatures, glacier melting, and changes in ocean chemistry [13].

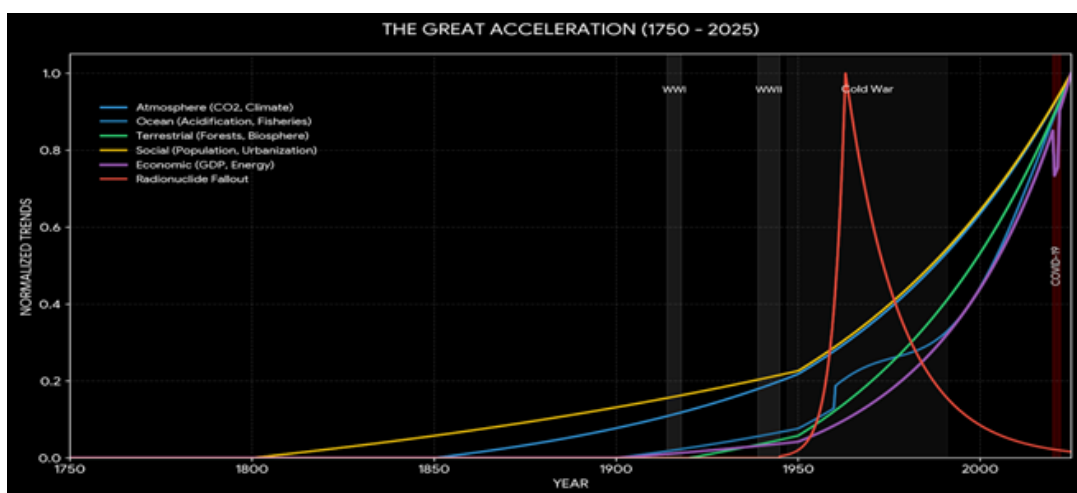


Figure 2. Dynamics of socio-economic and environmental changes during the Great Acceleration (1750–2025)

Climate Change and the "Great Acceleration"

The hydrosphere is also undergoing significant transformation. Phytoplankton, responsible for producing 50–80% of atmospheric oxygen, are affected by pollution and reduced sunlight penetration due to oil films and microplastics. Nutrient runoff from agriculture has created “dead zones” in over 500 marine regions, where oxygen levels are too low to support life. Furthermore, a new ecological system known as the plastisphere has emerged, consisting of microorganisms that inhabit microplastic surfaces. These plastics can transport toxins across oceans, contributing to global ecological instability. Geodynamic changes are another critical result. The melting of glaciers reduces pressure on the Earth’s crust, leading to isostatic rebound, while the extraction of resources such as oil and gas reduces lithostatic pressure, causing land subsidence and increased seismic activity [14].

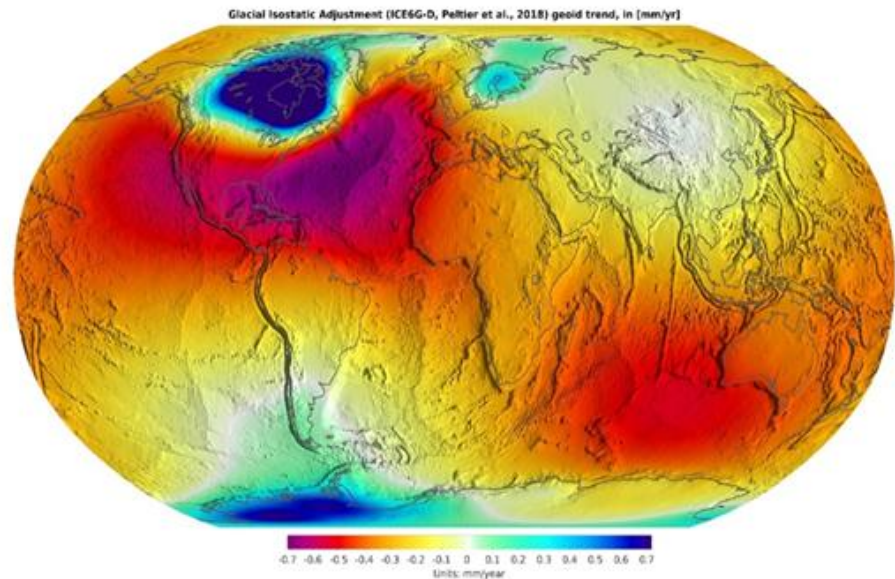


Figure 3. Isostatic rebound and lithospheric changes caused by mass redistribution

The Aral Sea provides a clear example of these processes. The rapid loss of water combined with gas extraction has created a complex geodynamic system involving both uplift and subsidence, demonstrating how human activity can alter tectonic behavior.

Discussion

The findings clearly demonstrate that the Anthropocene is not a hypothetical concept but a measurable transformation of the Earth system. The presence of technofossils, anthropogenic minerals, and new rock types indicates that human activity has penetrated deeply into geological processes, creating a distinct and lasting record. At the same time, ecological changes reveal a profound imbalance within the biosphere. The rapid decline of biodiversity suggests that natural systems are struggling to adapt to the speed and scale of human-induced change. This imbalance is particularly evident in marine environments, where pollution, warming, and acidification are disrupting entire ecosystems. Climate change acts as a central driver that amplifies these processes. Increased greenhouse gas emissions have altered atmospheric composition, leading to cascading effects across the hydrosphere and lithosphere [15]. The interaction between these systems highlights the complexity of the Anthropocene, where changes in one domain can trigger responses in others. The case of the Aral Sea illustrates the interconnected nature of these processes. Human intervention has not only transformed the local environment but has also affected geological stability, demonstrating that the impact of human activity extends beyond surface systems to influence the Earth’s internal dynamics. Debates regarding the beginning of the Anthropocene further reflect its complexity. Some scientists trace its origins to early agriculture, others to the Industrial Revolution, and many to the Great Acceleration of the 1950s. Recent efforts to define a formal geological boundary, such

as the selection of Crawford Lake as a “golden spike,” highlight the ongoing effort to establish a precise scientific framework. However, the decision by the International Union of Geological Sciences to classify the Anthropocene as a geological event rather than an epoch does not diminish its importance. Instead, it emphasizes the need for continued research and responsible management of human impact on Earth systems.

Conclusion

The evidence presented confirms that human activity has become a defining force in shaping the Earth’s geological, ecological, and climatic systems. From technofossils and radioactive markers to biodiversity loss and climate change, the Anthropocene represents a profound transformation of the planet. Although its formal classification remains debated, the reality of human influence is undeniable. The Anthropocene is not simply a scientific concept but a reflection of the new relationship between humanity and the Earth, one in which our actions carry long-term consequences for the entire planetary system. Ultimately, this understanding places a significant responsibility on humanity. The same forces that have transformed the Earth also have the potential to restore balance, provided they are guided by scientific knowledge and ecological awareness.

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