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Climate engineering and the role of geochemistry

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Combating climate change and its impacts is one of the 17 Sustainable Development Goals adopted by United Nations member states. The 2024 Annual Climate Summary, based on ERA5 (ECMWF Reanalysis v5) data produced by the Copernicus Climate Change Service of the European Centre for Medium-Range Weather Forecasts (ECMWF), reports that 2024 CE was the first calendar year in which the global average temperature exceeded 1.5°C above pre-industrial levels. Notably, the Intergovernmental Panel on Climate Change (IPCC) has warned that exceeding this threshold could lead to irreversible and irreparable consequences. While inadequate efforts of nations to reduce greenhouse gas (GHG) emissions may explain the situation, a pragmatic approach would be to persist in seeking lasting solutions to ensure continued human habitability on our planet. The multi-proxy approach, integrating geochemical and isotopic studies on foraminifera, ice cores, marine sediments, speleothems, and other archives, has provided a wealth of information on the duration and cyclicity of glacial and interglacial periods during the Pleistocene Ice Ages. Glacial periods lasted 80,000 to 100,000 years, whereas interglacial periods were shorter, lasting 10,000 to 20,000 years. The timing and periodicity of these cycles result from a delicate balance between orbital forcing and radiative forcing.

The current Holocene interglacial, which began after the Last Glacial Maximum, has now approached, if not exceeded, its expected duration. Yet, there is no sign of a return to a prolonged glacial period. This anomaly is largely attributable to anthropogenic disruption of the natural climate balance that has persisted for the past 2.5 million years. While anthropogenic GHG emissions are undeniably a major driver of current climate change, they have also prolonged the interglacial period, sparing humanity from a potentially harsher, colder glacial climate. Moving forward, it may be possible to establish a regulated climate feedback loop by optimizing GHG emissions through a quantitative assessment of alternative energy resources that could partially replace hydrocarbons. The first step in this process would be to develop a comprehensive geochemical database of all geological energy resources. A scientifically monitored radiative forcing, balancing orbital forcing, could help sustain the current interglacial while maintaining a more favorable climate.