# 10 questions shaping 21st-century earth science identified

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Ten questions driving the geological and planetary sciences were identified today in a new report by the National Research Council. Aimed at reflecting the major scientific issues facing earth science at the start of the 21st century, the questions represent where the field stands, how it arrived at this point, and where it may be headed.

"With all the advancements over the last 20 years, we can now get a better picture of Earth by looking at it from micro- to macro-perspectives, such as discerning individual atoms in minerals or watching continents drift and mountains grow," said Donald J. DePaolo, professor of geochemistry at the University of California at Berkeley and chair of the committee that wrote the report. "To keep the field moving forward, we have to look to the past and ask deeper fundamental questions, about the origins of the Earth and life, the structure and dynamics of planets, and the connections between life and climate, for example."

The report was requested by the U.S. Department of Energy, National Science Foundation, U.S. Geological Survey, and NASA. The committee selected the question topics, without regard to agency-specific issues, and covered a variety of spatial scales -- subatomic to planetary -- and temporal scales -- from the past to the present and beyond.

The committee canvassed the geological community and deliberated at length to arrive at 10 questions. Some of the questions present challenges that scientists may not understand for decades, if ever, while others are more tractable, and significant progress could be made in a matter of

years, the report says. The committee did not prioritize the 10 questions -- listed with associated illustrative issues below -- nor did it recommend specific measures for implementing them.

**HOW DID EARTH AND OTHER PLANETS FORM?**

While scientists generally agree that this solar system's sun and planets came from the same nebular cloud, they do not know enough about how Earth obtained its chemical composition to understand its evolution or why the other planets are different from one other. Although credible models of planet formation now exist, further measurements of solar system bodies and extrasolar objects could offer insight to the origin of Earth and the solar system.

**WHAT HAPPENED DURING EARTH'S "DARK AGE" (THE FIRST 500 MILLION YEARS)?**

Scientists believe that another planet collided with Earth during the latter stages of its formation, creating debris that became the moon and causing Earth to melt down to its core. This period is critical to understanding planetary evolution, especially how the Earth developed its atmosphere and oceans, but scientists have little information because few rocks from this age are preserved.

**HOW DID LIFE BEGIN?**

The origin of life is one of the most intriguing, difficult, and enduring questions in science. The only remaining evidence of where, when, and in what form life first appeared springs from geological investigations of rocks and minerals. To help answer the question, scientists are also turning toward Mars, where the sedimentary record of early planetary history predates the oldest Earth rocks, and other star systems with planets.

**HOW DOES EARTH'S INTERIOR WORK, AND HOW DOES IT AFFECT THE SURFACE?**

Scientists know that the mantle and core are in constant convective motion. Core convection produces Earth's magnetic field, which may influence surface conditions, and mantle convection causes volcanism, seafloor generation, and mountain building. However, scientists can neither precisely describe these motions, nor calculate how they were different in the past, hindering scientific understanding of the past and prediction of Earth's future surface environment.

**WHY DOES EARTH HAVE PLATE TECTONICS AND CONTINENTS?**

Although plate tectonic theory is well established, scientists wonder why Earth has plate tectonics and how closely it is related to other aspects of Earth, such as the abundance of water and the existence of the continents, oceans, and life. Moreover, scientists still do not know when continents first formed, how they remained preserved for billions of years, or how they are likely to evolve in the future. These are especially important questions as weathering of the continental crust plays a role in regulating Earth's climate.

**HOW ARE EARTH PROCESSES CONTROLLED BY MATERIAL PROPERTIES?**

Scientists now recognize that macroscale behaviors, such as plate tectonics and mantle convection, arise from the microscale properties of Earth materials, including the smallest details of their atomic structures. Understanding materials at this microscale is essential to comprehending Earth's history and making reasonable predictions about how planetary processes may change in the future.

**WHAT CAUSES CLIMATE TO CHANGE -- AND HOW MUCH CAN IT CHANGE?**

Earth's surface temperature has remained within a relatively narrow range for most of the last 4 billion years, but how does it stay well-regulated in the long run, even though it can change so abruptly" Study

of Earth's climate extremes through history -- when climate was extremely cold or hot or changed quickly -- may lead to improved climate models that could enable scientists to predict the magnitude and consequences of climate change.

**HOW HAS LIFE SHAPED EARTH -- AND HOW HAS EARTH SHAPED LIFE?**

The exact ways in which geology and biology influence each other are still elusive. Scientists are interested in life's role in oxygenating the atmosphere and reshaping the surface through weathering and erosion. They also seek to understand how geological events caused mass extinctions and influenced the course of evolution.

**CAN EARTHQUAKES, VOLCANIC ERUPTIONS, AND THEIR CONSEQUENCES BE PREDICTED?**

Progress has been made in estimating the probability of future earthquakes, but scientists may never be able to predict the exact time and place an earthquake will strike. Nevertheless, they continue to decipher how fault ruptures start and stop and how much shaking can be expected near large earthquakes. For volcanic eruptions, geologists are moving toward predictive capabilities, but face the challenge of developing a clear picture of the movement of magma, from its sources in the upper mantle, through Earth's crust, to the surface where it erupts.

**HOW DO FLUID FLOW AND TRANSPORT AFFECT THE HUMAN ENVIRONMENT?**

Good management of natural resources and the environment requires knowledge of the behavior of fluids, both below ground and at the surface, and scientists ultimately want to produce mathematical models that can predict the performance of these natural systems. Yet, it remains difficult to determine how subsurface fluids are distributed in heterogeneous rock and soil formations, how fast they flow, how effectively they transport dissolved and suspended materials, and how

they are affected by chemical and thermal exchange with the host formations.

Source: The National Academies