

## Sedimentary geology

[from **Sedimentary geology: the power of the long view** by C. Paola (U. Minnesota), C. Maples (Indiana U.), S. Holland (U. Georgia), S. Kidwell (U. Chicago), D. Mohrig (MIT), I. Montanez (U.C. Davis), B. Horton (U.C.L.A.)]

Earth's surface is "the environment" that supports all life and human activity.

Surface is the interface between solid-Earth, ocean, and atmosphere.

The stratigraphic record – a time sequence of depositional surfaces – is our window to the long view of surface dynamics.

It allows us to;

1. image alternative surface states and configurations on planetary time scales,
2. measure rates of change both abrupt and gradual,
3. study large-scale connections that are only weakly expressed on human time scales, and
4. give context to the snapshot that is the Earth's surface today.

Known major features of the Earth-surface system include self-organization, localization, autogenic fluctuations, strong history dependence, and strong interconnections.

Fortunately, we have the nearly four-billion year stratigraphic record and its numerous realizations of the behavior of the surface system. Only in the long record of Earth history can we measure the variability, and thus the predictability, of the planetary surface system.

## Grand Challenges

### **1. Understand how surface processes operate across the full range of planetary length scales, time scales, and conditions, including extreme states.**

As we move from human to planetary time and length scales our conceptual framework changes: the rare event becomes commonplace; slow but powerful tectonic sources and sinks become important; and the full array of Earth-system configurations emerges.

Our planet's history includes a remarkable array of extreme events and states (e.g., superwarming, snowball Earth, oceanic anoxia, CO<sub>2</sub> enrichment and elevated weathering, and changing composition of diversity and life).

**2. Understand the resolution, biasing, and filter properties of the stratigraphic record.** Because the stratigraphic record filters information about earth-surface conditions, our ability to image past states of the Earth is limited by our ability to quantify these filters in terms of both their deterministic and statistical components. For example, stratigraphic sequences control patterns of species' first and last occurrences, affecting the reliability of biostratigraphic correlations, evolutionary interpretations and paleoecological reconstruction. Similarly, the same processes that control time-averaging and stratigraphic architecture also modify geochemical and other proxy data for ecological, climate and other environmental analyses.

**3. Determine the roles of organisms in Earth-surface dynamics.** Research in surface dynamics on all time scales demonstrate the myriad ways in which organisms influence and are influenced by surface conditions and processes.

The evolution of life has had major impacts on Earth's surface at several scales, such as the colonization of land by plants.

Among organisms, humans have affected Earth-surface systems through the introduction of greenhouse gases, overturning and mixing of surface materials, modifications of stream flow and runoff,

and elevation of solute and solid loads to the seas. Geohistorical records are the only means to acquire the baseline information on natural variability against which anthropogenic effects must be measured.

**4. Use the sedimentary record to develop and evaluate Earth-system models.** Theoretical modeling of surface dynamics is developing rapidly. But Earth’s surface, with strong nonlinearity and many interacting parts, can behave in unexpected ways that make theoretical modeling futile unless paired closely with observation.

If the Earth’s surface were simple enough, we could test surface-process models in the modern world over short time scales and then just extend them to long times to reproduce Earth history. But everything we know about complex, nonlinear systems suggests that this would be a very naïve approach. System-scale models must be tested on the time and space scales over which whole-system behavior is played out. In the case of the Earth’s surface this means model testing on planetary time scales. The only surface data available on these time scales are those recorded in stratigraphy.

Ultimately, we must try to “break” our models by taking them to their limits. Any reliable general model must reproduce the behavior of non-analog worlds as well the singular modern world. To do that, we need data from the Earth at its limits: periods of crisis and extremes such as anoxia, biotic crises, and climatic extremes.

The fundamental challenge of sedimentary geology: developing an analytical understanding of Earth-surface history.

*Analytical* = estimating paleovariables quantitatively rather than settling for qualitative descriptions.

Sedimentary rocks only make up 5% of the Earth's crust, but cover about 75% of the surface of the earth.

Sedimentary rocks have an average thickness of about 1800 m on the continents. This thickness is quite variable, however, with some areas, like the Canadian Shield having no cover of sedimentary rocks, and other areas, like the Louisiana and Texas Gulf coasts, having more than 15,000 m of sedimentary rock cover. About 66% of all continental areas have a cover of sedimentary rocks.

Because sediment gets buried, and if exposed is subjected to erosion, older sedimentary rocks show less exposed outcrop area than younger sedimentary rocks. Over 40% of the exposed sedimentary rocks are younger than Cretaceous in age.

