EXECUTIVE SUMMARY: EARTHCUBE WORKSHOP RESULTS

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Earth Cube Workshop Title: Calling All Experimentalists- Experimental Stratigraphy

Introduction: Approximately 55-60 Earth-surface scientists gathered for a workshop held at the University of Texas (UT) at Austin over 12/11-12/12. The participants include groups of 18 from Japan, Korea and Europe and a group of 35 from the U.S., 20 of whom came from outside UT. Costs for the Japanese participants to travel to the workshop were leveraged from the JSPS funds they obtained separately. In addition the implementation of an online forum resulted in remote participation of another 7-10 scientists over the two days, including participants from Canada and Taiwan. Overall the size and diversity of the participating group played a substantial role in the success of this workshop.

Over the course of two days, participants carried out a set of community experiments, heard presentations from 7 keynote speakers, and held group discussions. The speakers specifically addressed the range of issues from their vision for the experimental Earth-surface science community, to recent scientific successes, to grand challenges that experimental science can address, and to community needs in pursuit of these goals.

The community experiments were conducted using input solicited from participants prior to the workshop. These experiments served as a focal point of discussion during the first day of the workshop and to facilitate openness during discussion through shared experience. In this effort partial experiments carried out by one subgroup were interpreted by another subgroup. This is all documented and publicly available through the workshop website (URL, https://sites.google.com/site/sedimentexperimentalists/workshop-experimental-stratigraphy). Beyond the results of the experiments, all other workshop materials, notes, and many presentations can also be accessed through the website.

Over the course of the workshop, three focused breakout discussions were led in addition to general, plenary discussion during experiments and keynote presentations. The break-out discussions were tied to each day's themes: day 1, current practices; day 2, current & future needs and best practices. The smaller discussion groups, 12-15 participants each, explored these themes for approximately one hour with notes taken. In addition, questionnaires were distributed to participants each day in both hardcopy and digital format. Along with the questionnaires, the presentations and discussions form the basis for the remainder of this document.

SCIENCE ISSUES AND CHALLENGES

Important challenges for advancing experimental stratigraphy: Participants identified several high-priority science issues that will be central to advances over the next 5-15 years

- How do we apply technical advances currently underway to experimental methods to create the next major advances in scientific knowledge? This will allow us to answer standing questions as well as ask completely new ones. These methods are likely to include:
  -Tomographic methods for the detailed *in-situ* investigation of strata as the evolve.
  -Long-range particle tracking methods for developing Lagrangian framework theories for sediment transport and deposition.

-Computational methods for measuring and modeling individual sediment grains in large, complex systems.

- What framework and model will allow us to gather and distribute large experimental data volumes for broad use beyond the original investigation? This is key to extracting greatest value from experimental data, increasing scientific efficiency at community level, and enhancing collaborations within and beyond the experimentalist community.

- How can directly coupling laboratory experiments to outcrop-based investigations accelerate advances in understanding? This approach is an excellent one for addressing major issues including:
  -Testing field-derived stratigraphic models (i.e. those directly tied to reservoir problems).
  -Addressing the grand challenge of integrating autostratigraphy and sequence stratigraphy.
  -Overcoming the community reluctance to incorporate experimentally-derived stratigraphic knowledge into stratigraphic models.

Current challenges to high-impact, Earth-surface science applications: Several themes emerged as consistent challenges faced within the discipline and its application to other disciplines

- How can we harness the collective abilities of the experimental community to conduct focused, timely experiments that would result in accelerated ability to answer large-scale questions. This model essentially divides up "parameter space" between various experimental facilities such that all conduct part of a single set of experiments together. The clear trade-off between number of participating facilities and time to complete experiments would allow for quick return on investment from many investigators.
- Will searching for general properties of sediment transport systems and stratigraphy move the community beyond applications of scientific knowledge by specific environment (e.g. delta, etc.? add a few examples? depositional versus erosive; subaerial versus subaqueous)?

- Can we specifically focus on remotely sensed data (e.g. image, topography, composition) for Earth landscapes and seascapes to provide tools for interpretation of these types of data on other planetary bodies. Remote sensing of environments and surfaces of extraterrestrial bodies is rapidly growing, and developing connections to exploration beyond Earth will be greatly aided by complete embrace of these data types for terrestrial systems.

TECHNICAL INFORMATION/ISSUES/CHALLENGES

Current and future needs for pursuing key science questions with brief elaboration:

- Many of the identified needs and challenges bridge the gap between scientifically technical issues and cultural issues of our scientific community. While many technical issues could be addressed at the individual investigator level, a community-scale effort would likely result in greater efficiency, and it is paramount for creating lasting cultural solutions. Most all needs identified below fit into this framework.

- Cultural: Difficulties with incentives for data sharing
  -Intensive in time and financial resources to produce an effective data sharing platform
  -No rewards for this kind of investment. Possible reward types could include

-Institutional support, i.e. recognition during tenure process
-Incentives from NSF for public data availability or reuse
-Recognition for data generation distinguished from interpretation in literature
-For long-term monitoring a funded investigator should still get to work exclusively with new data on interpretations before sharing
-Lack of long term solution disincentivizes investment in resource
-Scientists spend time on science and not on management

- Technical: Need for expertise in data issues within our community
  -No expert resources to call on for guidance and assistance in management
  -Need training for data management for students, etc. from the beginning of the project
  -Many institutions do not offer IT support to investigators

- Considerations for international cooperation
  -Language is a problem. For example, programming comments all in Japanese may be easier for the individual Japanese investigator but may create challenges in sharing code.
  -International agreement on sharing of data is an issue.
  -Coordination of physical and financial resources for hosting data is an issue.

- Opportunities to put our discussed ideas into action and test
  -Testbed data sharing site could be served distributively with single front-end combining data, metadata, models, etc.
  -Trial solution for linking documentation with data
  -Individual investigators can work independently to test differing solutions allowing faster discovery of models that do not work well. Compels move to more open source solutions.
  -Allows for growth of merit-based solutions in data/metadata structuring, i.e. not prescribed by committee but determined by acceptance and use
  -Opportunity to test if this expedites secondary use of data to answer broader scientific questions
  -More funded community discussions to further advance a plan for data storage and dissemination . ie: We have not gotten it all done in two days but current ideas can be verified or discarded.

- A funding model to make the dreams work - what would the funding model be? Institutional support / national agency / scientific organization

SCIENCE SCENARIO EXAMPLE

The following scenario is a typical example of a laboratory experiment in stratigraphy- one that attempts to understand process controls on coastal stratigraphic construction through manipulation of boundary conditions. This is a generalization of the group experiment that was run during the workshop. Similar experiments, specifically those incorporating sea level rise / fall, changes in sediment supply, and/or differential subsidence are common today because they relate to such diverse issues as coastal change, natural hazards, and natural resource exploration.

Experimental inputs and data types would include mass fluxes of fluids and sediments, normally these are variables for which a time series is recorded. The other boundary conditions would likely include a “sea level” curve and subsidence pattern. Again both being time series datasets and the subsidence would have a component of spatial variation and could also be represented as an evolving contour map through time. Other relevant data would include information about granular hydrodynamics, geometry of the experimental apparatus, and metadata regarding the details of the setup that would normally not be reported beyond a qualitative fashion. In order to quantitatively relate the boundary conditions to the resultant stratigraphic condition a range of observations might be made during and subsequent to the experiment. These might include repeat surveys of surface topography and bathymetry. Like subsidence, this is appropriately conceptualized as an evolving map. Time-lapse photography and derivative digital data such as shoreline position or distribution of channels or sediment type are often collected. Being directly derived from time-dependent spatial data, these types would have equivalent natures. Finally, the interests in stratigraphy itself compels a 3D spatial data that could be arrived at through physical dissection of deposits or through various types of remote sensing such as ultrasonic pseudo-seismic. These data could also be collected through time resulting in a 4D manifestation of a single stratigraphic property (e.g. grain size) (sliced deposit sections following completion of the experiment).

It is worth pointing out that methodologies for experiments of this type is diverse enough that it could have substantial impacts on the data recorded. Depending on technologies used, there is a direct trade-off between quantity of information and ability to record it. While those facilities that use computer-based control of boundary conditions can often record with greater temporal sampling rates, those that use manual controls are often much more limited in the data volumes associated with boundary condition changes. Similarly, in the latter, all notes (both inputs and observations) would likely be recorded by hand in participant notebook while the former is recorded digitally during the control process. Example data from our group experiment can be found through the workshop website (URL, https://sites.google.com/site/sedimentexperimentalists/workshop-experimental-stratigraphy).