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Collaborative Research: Erosional Forcing of Late Quaternary Compressive Strain, West Central Taiwan

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Principal Investigator: Upton, Phaedra . **Award ID:** 0510051

Organization: University of Maine

Submitted By:

Upton, Phaedra - Principal Investigator

Title:

Collaborative Research: Erosional Forcing of Late Quaternary Compressive Strain, West Central Taiwan

Project Participants

Senior Personnel

Name: Upton, Phaedra

Worked for more than 160 Hours: Yes

Contribution to Project:

Contribution to Project: Phaedra Upton is responsible for developing three-dimensional mechanical models of deforming and eroding wedges with reference to the Puli region of Taiwan.

Post-doc

Graduate Student

Undergraduate Student

Technician, Programmer

Other Participant

Research Experience for Undergraduates

Organizational Partners

University of Colorado at Boulder

National Taiwan University

Other Collaborators or Contacts

Peter Koons, University of Maine
Assistance and discussion about numerical modelling

Yue-Gau Chen and students, National Taiwan University
Discussion about geology of Puli Basin.
Led fieldtrip to show the PI the field area

Mueller, Karl, University of Colorado at Boulder
Tucker, Greg, University of Colorado at Boulder

Activities and Findings

Research and Education Activities:

Upton spent 10 days in Taiwan in May 2009. While this trip was largely funded by other projects and its main aim was investigation of fluid flow and gold deposition within the Taiwanese mountains, some time was dedicated to this project. A day was spent at the National University of Taiwan talking with Yue-Gau Chen and John Suppe about our work. Puli and the Lishan region were also visited.
Upton has continued to develop three-dimensional models aimed at investigating the effect of surface processes on the Puli region and the results are published in Upton et al. (2009).
In September 2008, Upton spent a week at the University of Colorado, Boulder with Mueller, Tucker and their students. She was brought up to date on their field studies and presented her latest modelling results to the group. Tucker and Upton finished developing the MatLab code that controls coupling of FLAC3D and CHILD. Preliminary models have been run and sensitivity analysis of mechanical and erosion parameters is planned.
A manuscript that was submitted in 2008 to the Journal of Geophysical Research on 3D mechanical models of eroded wedges has been reviewed, revised, and published (Upton, P., Mueller, K. and Chen Y-G., (2009) 3D numerical models with varied material properties and erosion rates: Implications for the mechanics and kinematics of compressive wedges. Journal of Geophysical Research û Solid Earth. 114, B04408, doi:10.1029/2008JB005708.).

Findings: (See PDF version submitted by PI at the end of the report)

Research Findings û Phaedra Upton, University of Maine, Summary of work 07/08 to 07/09
A series of three-dimensional mechanical models were run to investigate how the form and kinematics of an outboard wedge, such as the western side of Taiwan, responds to variations in initial topography, material properties and erosion rate. If a wedge is sub-critical, either as a result of missing topography, the incorporation in the wedge of lower density material or of enhanced erosion, the wedge will focus material into that region in an attempt to rebuild itself to criticality. As this part of the wedge rebuilds, the regions inboard are deprived of material, resulting in a new area that is sub-critical and has lower topography. In our models, an imposed erosion rate of 3 mm/yr was sufficient to produce and maintain a topographic depression within the outboard of the model. Material is focused into the eroded region and is withheld from the region inboard. This leads to the development of a stepped region of lower topography within the model.
We observed that deformation within the models was not uniform with time and we suspect that this is likely to be the case for real fold and thrust belts as well. The uplift velocities at the locations monitored varied cyclically from near zero to ~3X the average uplift rate. Over the runtime of the model, the whole outboard region deforms, however, the focus of active deformation shifts on short spatial and temporal scales. At any one time, activity may be concentrated onto more or more structures. These cycles last on the order of 15-200,000 model years. Our models suggest that transient accommodation of strain may be common. Thus, caution should be applied when extrapolating long-term slip rates from varying temporal scales. The cycles observed respond rapidly to changes in the amount of erosion imposed. Our models suggest that orogens may be driven by remarkably strong coupling between erosion and strain, on temporal scales of 104-105 years and spatial scales comparable to the scale of the erosional perturbation.
Comparing our models to the Puli Embayment of west-central Taiwan, a region of anomalous low topography suggests that the embayment may reflect the presence of weaker and more erodible sediments than those present along strike in the orogen. Inboard of the range front, deformed terraces and rapid incision rates imply that the Shuilikeng Thrust is active. Our models suggest that removal of material from the Puli Embayment may be contributing to deformation stepping back to the basin, onto the Shuilikeng Thrust.
Much of the time this year was spent finishing development of the scheme to couple FLAC3D and CHILD. This was completed although further development is planned. Preliminary models run with this scheme show that our Matlab code works. We intend to continue this work even though this project has now come to an end. In particular, we plan to modify the codes so that we can investigate the linkages resulting from deformation induced weakening of rock.

Two mp3 files showing preliminary results of the coupled models will be emailed to the program manager. The description of these movies is below.

Movie1 - ErosiveMaterial.mov
Movie shows a coupled model of a deforming and eroding two sided wedge. The mechanics are solved in FLAC3D and the surface processes in CHILD. Colors represent contours of elevation, blue = 0m, red = 110m. Arrows show the movement of material through the wedge. In this model, the material is very erosive and the wedge only develops ~110 meters of elevation.

Movie2 - NonErosiveMaterial.mov
Movie shows a coupled model of a deforming and eroding two sided wedge. The mechanics are solved in FLAC3D and the surface processes in CHILD. Colors represent contours of elevation, blue = 0m, red = 1000m. Arrows show the movement of material through the wedge. In this model, the material is not erosive and the wedge develops ~960 meters of elevation.

Training and Development:

Development of software to couple FLAC3D and CHILD finished.

Outreach Activities:

We undertook no formal outreach activities for schools or public-related presentations during the 2008-2009 reporting period.

Journal Publications

Upton, P., Mueller, K., Tucker, G., Wilcox, T., Yanites, B, "Do higher erosion rates lead to topographic highs or lows? An example from the Puli Embayment, West-Central Taiwan", Eos Trans. AGU, 87(52), Fall Meet. Suppl., p. T24B-07, vol. 87(52), (2006). Published,

Upton, P., Mueller, K. and Chen Y-G., "3D numerical models with varied material properties and erosion rates: Implications for the mechanics and kinematics of compressive wedges", Journal of Geophysical Research â?? Solid Earth, p. , vol. , (2009). Published, 10.1029/2008JB005708

Books or Other One-time Publications

Web/Internet Site

URL(s):

http://www.geology.um.maine.edu/HTML-ERS/Projects/ProjectsGCS_Puli_Taiwan.htm

Description:

Other Specific Products

Product Type:

Software (or netware)

Product Description:

I have developed a module for FLAC3D, a commercial mechanics package that I use in my research, which allows me to couple the mechanical part of the code with the thermal through the rheology and the temperature. The module will be useful in determining the extent of crustal thermal perturbation that occurs as a result of erosion enhanced uplift in Taiwan.

Sharing Information:

This module is quite specific to the problems we address in the Geodynamics Modeling Laboratory at the University of Maine. It is available to graduate students and others working in the Geodynamics lab and they will likely modify it for their own specific problems.

Contributions

Contributions within Discipline:

We have developed fully three-dimensional models of the Puli region which take into account the tectonic and the surficial boundary conditions. This is a significant advance upon previous two-dimensional models of the Taiwan orogeny which did not take into account along strike variation in the orogen. We have developed a 3D coupling between a mechanical code and a landscape evolution code.

Presentations
Upton, P., Coupled mechanical-landscape evolution models. Source-to-Sink workshop, Wellington, New Zealand, 28th November 2008.
Upton, P., and Craw, D., Mountains, fluids and gold in Taiwan, University of Otago, July 29th 2009
Upton, P., and Craw, D., Mountains, fluids and gold in Taiwan: comparison with the Southern Alps, GNS Science, August 6th 2009

Contributions to Other Disciplines:

This three-dimensional models have yielded new results that bear on the temporal nature of repeating earthquakes within active thrust belts. These results suggest caution must be applied when extrapolating long-term slip rates from varying temporal scales.

Contributions to Human Resource Development:

Contributions to Resources for Research and Education:

Flac3D modules created by Upton for thermo-mechanical modeling are being used by graduate students at UMaine involved in other NSF funded projects.

Software to couple Flac3D and CHILD will be used by graduate students at UMaine.

Contributions Beyond Science and Engineering:

Conference Proceedings

Categories for which nothing is reported:

Any Book

Contributions: To Any Human Resource Development

Contributions: To Any Beyond Science and Engineering

Any Conference

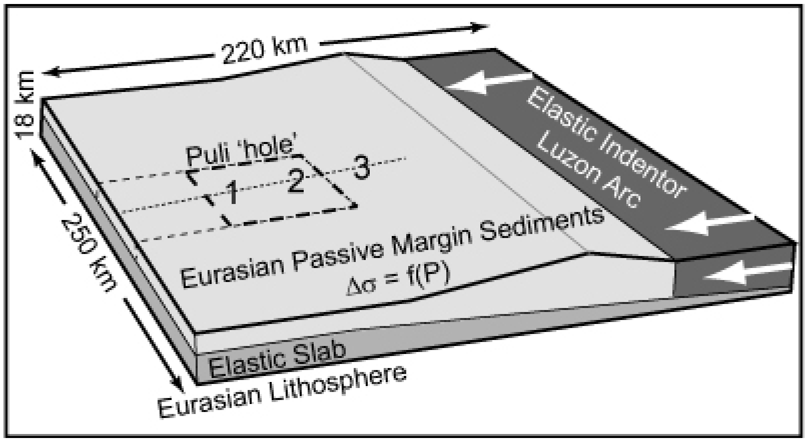

Figure 1: A: Model geometry, material properties and boundary conditions. The bold dashed line outlines the region of the Puli "hole". In some models this is a pre-existing hole, in others a region of more intense erosion. The lighter dashed line outlines the region of weaker, less dense sediments included in some models. See text for details of individual models.

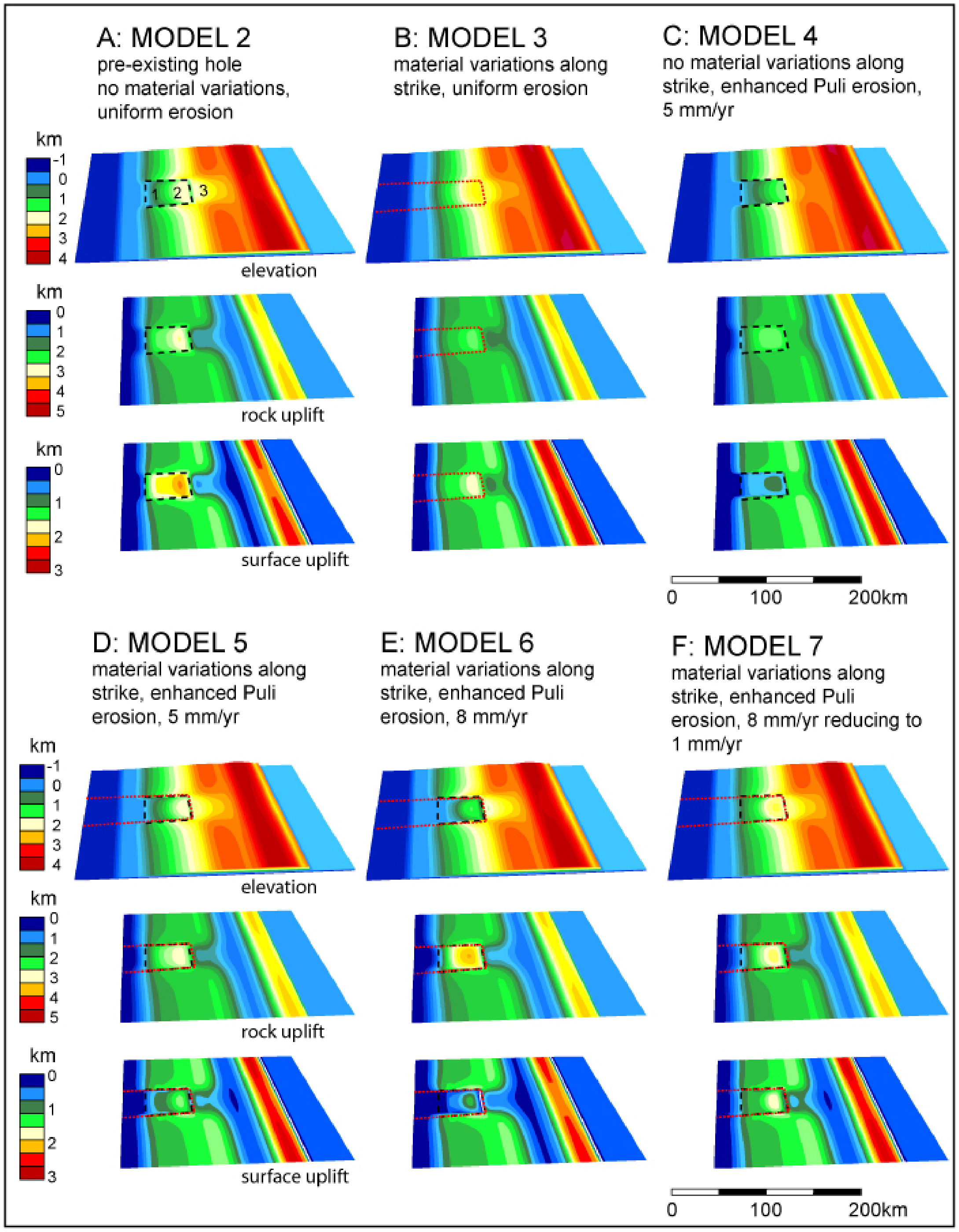

Figure 2: Contour plots showing elevation, rock uplift and surface uplift (km) at the end of the model runtime for six of the models discussed in the text. Black dashed box represented pre-existing hole in A and region of enhanced erosion in C, D, E and F. Red dashed box represents region of different material properties in B, D, E and F. A: Model 1 with a pre-existing hole and no focused erosion in the Puli region. B: Model 2 with weaker, less dense material in the Puli region and no focused erosion. C: Model 3 with uniform material and enhanced erosion (5 mm/yr) in the Puli region. D: Model 4 which combines models 2 and 3. E: Model 5 as for model 4 but with faster erosion in the Puli region. F: Model 6, as for model 5 but erosion in Puli is reduced in the later stages of the model runtime. See text for details of the model results.

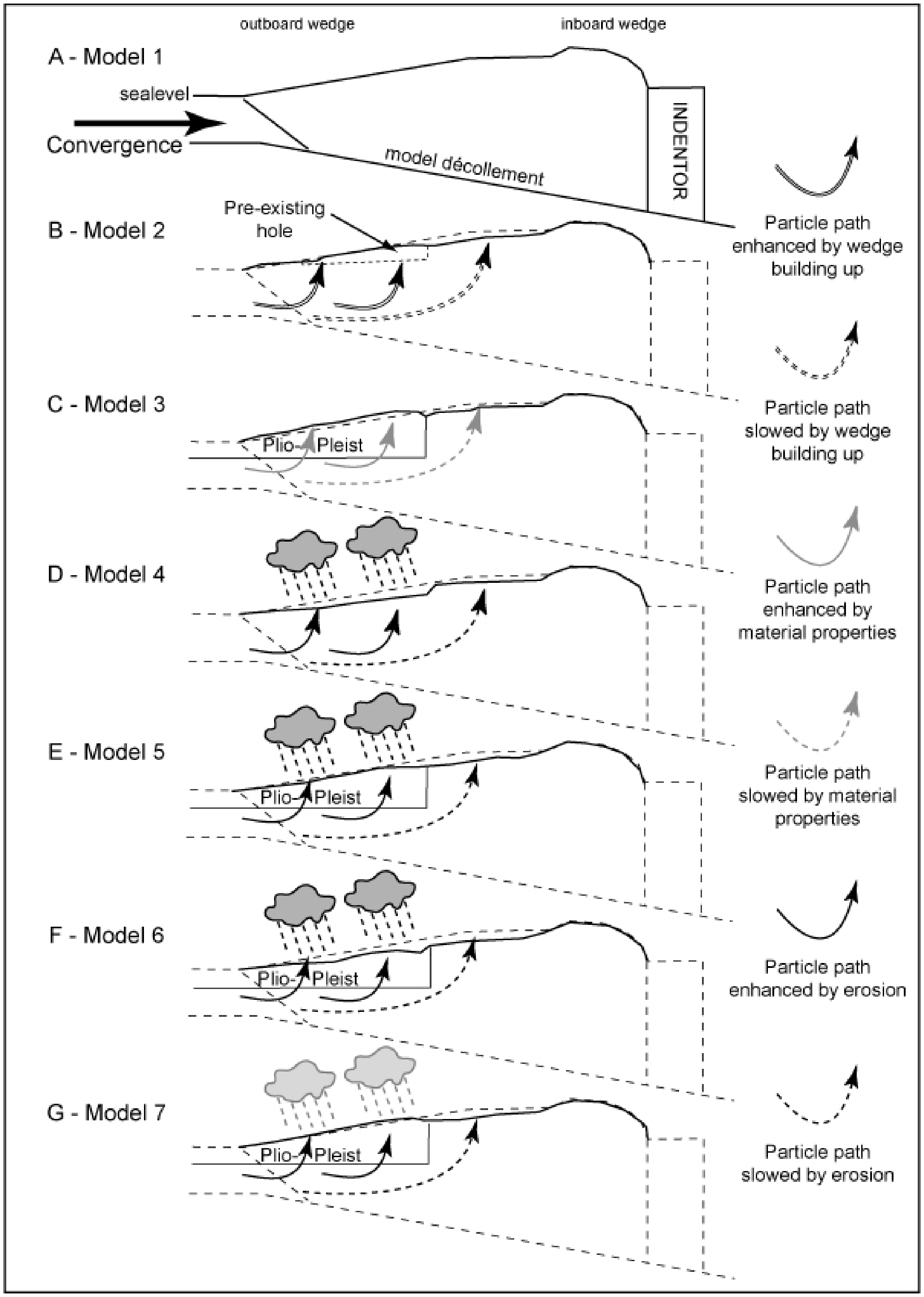

Figure 3: Synopsis of results. Schematic outline (vertical exaggeration ~3X) of the model wedge for different material properties and erosion schemes. The dashed lines in B-G are the outline of the reference model. (A) Reference model (B) Model with a pre-existing hole (C) Uniform wedge with Puli erosion = 5 mm/yr (D) Weaker, less dense Plio-Pleistocene sediments in the Puli region (E) Weaker, less dense Plio-Pleistocene sediments in the Puli region with Puli erosion = 5 mm/yr (F) Weaker, less dense Plio-Pleistocene sediments in the Puli region with Puli erosion = 8 mm/yr (G)Weaker, less dense Plio-Pleistocene sediments in the Puli region with Puli erosion = 8 mm/yr reducing to 1 mm/yr.