Progress Report: 2004 SCEC Proposal

Development of the SCEC Community Vertical Motion Map

Nathan Niemi[1], Principal Investigator

Mike Oskin[2], Co-Principal Investigator

Tom Rockwell[3], Co-Principal Investigator

[1]Division of Geological and Planetary Sciences, California Institute of Technology

[2]Department of Geological Sciences, University of North Carolina at Chapel Hill

[2]Department of Geological Sciences, San Diego State University

Introduction
The vertical motion database project seeks to integrate disparate sources of geologic uplift and subsidence data into a single resource for investigations of permanent crustal deformation in southern California. Data gathering from the geology literature proceeds simultaneously with construction of customized data models that faithfully represent each data type. The database is available to the SCEC community via a web interface located at http://geomorph.geosci.unc.edu/vertical. Efforts are underway to integrate the vertical motion database with other SCEC data products (e.g. the FAD and the CFM) via a unified map-based interface to be hosted under the SCEC web site.

Vertical Motion Database and Map - 2004 Achievements
(1) We completed the compilation and correlation of marine terraces from Point Conception to the Mexican Border. There remain a few problematic data points to enter for the Ventura area terraces, but this will be completed by years end. The marine terrace data set includes all localities where we could find published and unpublished information on paleoshoreline elevation and terrace age (U-series, amino acid data, distinctive faunal assemblages, etc.), with specific emphasis on the terraces associated with the last major interglacial period (80 to 120 ka). Where a terrace locality is directly dated with U-series on coral, we used that as a primary tie to correlate other age data and elevations.

(2) Concurrent with gathering of marine terrace locations and ages, data models were constructed in a PostgreSQL object-relational database to represent marine terrace data. A base locality table contains information common to all vertical motion data, such as measurement location, present elevation, and age constraint, whereas a specialized marine terrace subclass of the locality table contains information specific to marine terraces, such as the terrace gradient and shoreline angle elevation. Likewise, a base geochronology table holds information common to all age determinations, while specific subclass tables hold specialized data for particular geochronology methods. Tables may be queried generically, to yield consistent location, elevation, and age information; or a specialized subclass table may be queried individually to return specific information relevant to a particular data type.

In addition to modeling geologic data in an object-oriented, hierarchal manner, the vertical motion database takes advantage of the recursive query capability of PostgreSQL to model correlations in the data set. Both the locality table and the geochronology table may contain correlations to other localities rather than actual age measurements. For localities, this approach models the often sparse distribution of age constraints in the geologic data sets. For geochronology, this approach models relative dating techniques, such as amino acid racemization, that require calibration with absolute dating methods.

Rather than present a static set of vertical motion results that are inherently dependent on a choice of reference frame, the Vertical Motion Database contains multiple reference frames that may be applied to convert geologic measurements into uplift rates. For example, while the present marine terrace elevation can be measured from a topographic map, its paleoelevation is dependent on competing models paleo-sea level. The philosophy behind the construction of the Vertical Motion Database is to present the data separately from reference frames. The Vertical Motion Database presents reference frame information to the user as the second step of a two-step query process, thereby engaging the user in making choices that affect interpretation of the vertical motion results.

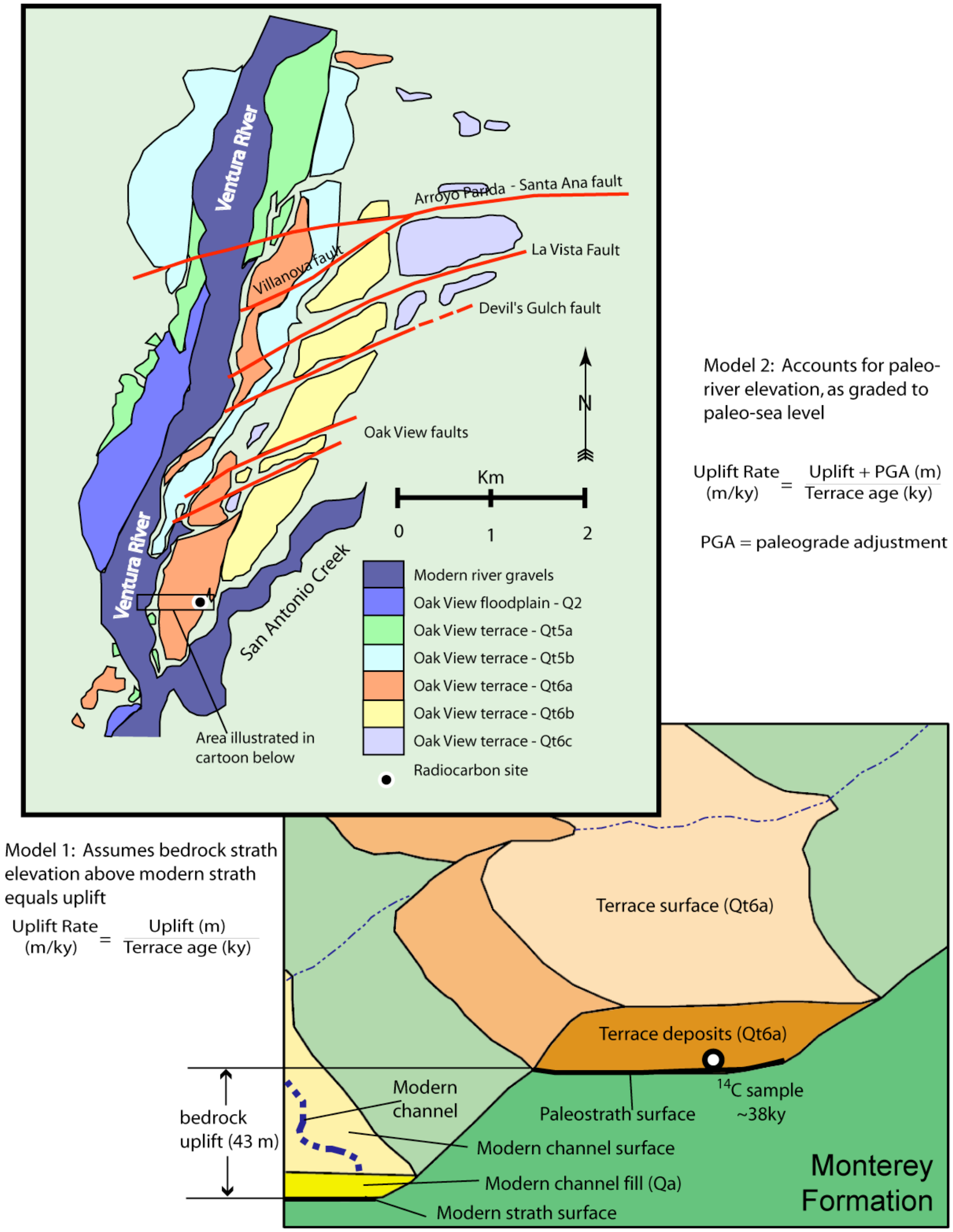


Figure 1: Illustration of fluvial terrace map data and reference frame models 1 and 2 described in text. User of vertical motion database makes choice of reference frame as part of processing data to yield vertical rates.

(3) We began work on incorporation of data on fluvial terraces, which are ubiquitous throughout southern California. Because fluvial terraces grade to a base level that is not

always known, the uplift that is inferred is, in part, reference frame dependent. Thus, we developed a system that incorporates primary data (terrace surface elevation, strath elevation, terrace age, spatial location) that can be utilized by models of terrace formation. A simple reference frame model (model 1) takes the elevation of the bedrock strath above the modern strath as uplift since the strath was cut (Figure 1). This assumes, of course, that the river has not changed its position relative to the modern river, and therefore modern sea level. As this is unlikely, we also present model 2, which incorporates a value for adjustment of the paleo-river grade. Critical in model 2 is knowledge of the precise age of the terrace and its fill surface, as we necessarily utilize paleosea level estimates as the basis for establishing paleo-grade near the coast. For high-stand terraces, there grades are comparable to the present, approximating model 1. However, some terraces in areas of higher uplift may correlate to interstadial or low stands, requiring additional knowledge of paleo-grade.

We are utilizing the published Ventura River terrace sequence as a test case (Figure 1), as the terraces are already mapped, their ages are well known and the fill thicknesses have been previously measured. Further, there are terraces along the Ventura River that correlate to high, intermediate, and low periods of sea level due to the very high uplift rates, so we can develop and test models that incorporate varying base levels to see if there is a unique solution for rate. If so, we can apply that terrace response model to other, less well-dated river systems throughout southern California. An important caveat is that there will be an obvious need for new chronometric data on terrace ages for the major rivers in Los Angeles once the terrace reference frame issues are resolved.

(4) We have begun incorporating aquifer data, provided by Karl Mueller, and stratigraphic data from published sources, for the greater Los Angeles basin. Aquifer and stratigraphic data have many of the same issues as fluvial terraces, as they are essentially buried river channel or marine deposits formed at an elevation other than sea level. For shallow marine strata, biostratigraphy can provide some control on paleodepth. For non-marine strata, we plan to apply a variation of our fluvial terrace model.

(5) A large data set of thermochronologic data across southern California present a potentially rich data set for study of vertical motions. Thermochronologic ages represent exhumation of rocks through a closure temperature, usually at 2 km depth or greater. Thus, in order to measure young ages at the surface requires 2 km or more of erosion! Typically this does not occur within a 10^5 year time frame, except in the exceptional case of Yucaipa Ridge in the San Gorgonio Pass. However, age-elevation transects of thermochronologic data can provide a robust measure of exhumation (a proxy for rock uplift rate) at the 10^6 year time scale, which we include in the Vertical Motion Database. We have constructed age-elevation profiles for several of the rapidly uplifting and eroding parts of the Transverse Ranges from published data, and are at present working on a model to incorporate these results into the Vertical Motion Database. Thermochronologic ages can also establish relative erosion levels into once-stable surfaces, such as the Mojave Desert, San Bernardino Mountains, and the Peninsular Ranges. Through reconstruction of these erosion levels, we are presently working to determine regional uplift and warping of surfaces across major faults.

(6) We have successfully introduced web access to the Vertical Motion Database. The database is built on the open-source PostgreSQL relational database server running on a Mac G5 Xserve at the University of North Carolina. This server also hosts the Vertical Motion Database web access portal, located at http://geomorph.geosci.unc.edu/vertical (Figure 2). The web site is built on the PHP scripting language, which permits interaction with users via web-based query forms. The web site program derives all of its processing instructions from tables stored in the vertical motion database. This strategy permits the site to immediately expose new localities and even new data types as these are entered into the database. Presently, vertical motion results are output to the browser as an HTML table. Future additions to the web site will include the ability to download results in ArcGIS or GMT compatible formats, and enabling automated access to the database as a web service via PHP. The web site will also be enabled to accept queries from the SCEC unified map-based interface.

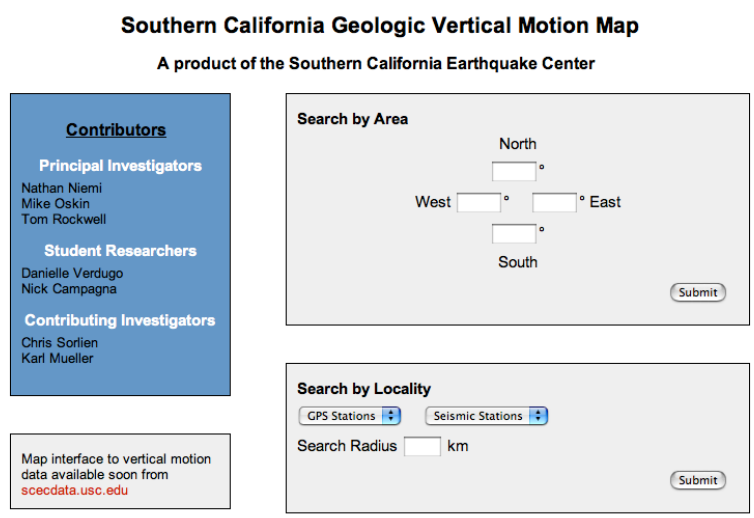


Figure 2: Web interface to the vertical motion database. Searches may be conducted by area or by proximity to a GPS or Seismic station. The SCEC data portal, presently under construction, will support map-based queries.

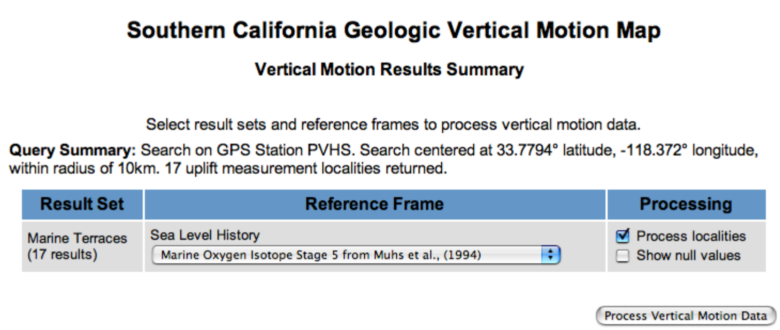
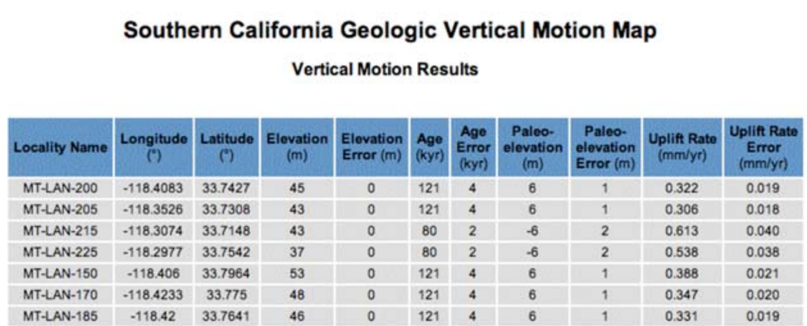


Figure 3: Results of query on PVHS GPS station. Query located 17 vertical motion data points within a 10 km radius. The user is prompted to select a reference frame and proceed to processing localities into uplift rates.



Southern California Geologic Vertical Motion Map

Vertical Motion Results

Locality Name	Longitude (°)	Latitude (°)	Elevation (m)	Elevation Error (m)	Age (kyr)	Age Error (kyr)	Paleo-elevation (m)	Paleo-elevation Error (m)	Uplift Rate (mm/yr)	Uplift Rate Error (mm/yr)
MT-LAN-200	-118.4083	33.7427	45	0	121	4	6	1	0.322	0.019
MT-LAN-205	-118.3526	33.7308	43	0	121	4	6	1	0.306	0.018
MT-LAN-215	-118.3074	33.7148	43	0	80	2	-6	2	0.613	0.040
MT-LAN-225	-118.2977	33.7542	37	0	80	2	-6	2	0.538	0.038
MT-LAN-150	-118.406	33.7964	53	0	121	4	6	1	0.388	0.021
MT-LAN-170	-118.4233	33.775	48	0	121	4	6	1	0.347	0.020
MT-LAN-185	-118.42	33.7641	46	0	121	4	6	1	0.331	0.019

Figure 4: Results of the above query and processing instructions. 7 of 17 results produced uplift rates with the selected reference frame.