Towards Development of a Vertical Motion Database for Southern California

A SCEC Undergraduate Research Experience Project

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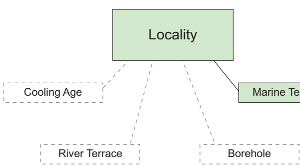
ABSTRACT

Towards the development and population of a database on long-term vertical velocities, we began compilation of information on the ages and elevations of marine and fluvial terraces in coastal southern California, and rock uplift information derived from low-temperature thermochronology. Surface uplift rates are calculated as the difference between a terrace's current elevation and the elevation at which it formed, relative to today, divided by the terrace age. We identify three primary sources of uncertainty: terrace age, elevation of the marker feature (ie. paleo-shoreline), and elevation of the reference frame (paleo-sea level or river channel level). For terrace age, we compiled all relevant information including radiometric age (C-14, U-series or other age data, including all isotopic ratios), amino-stratigraphic information, faunal assemblage zoogeographic data including inferences from southern and northern extra-limital species, and other age data (cosmogenic, OSL, TL dates). Elevation data are compiled from primary sources and include both surveyed and topographic elevation information on the shore platform, paleo-shoreline or terrace tread. Estimates of paleo-sea level are potentially the most problematic, as California observations appear somewhat at odds to estimates from Barbados and New Guinea. We have developed three alternative sea level models that we test against the terrace observations, all of which agree at the 0.1 mm/yr level.

All terrace information has been entered into a Geographic Information System database (Arc/INFO), and geo-referenced into a common coordinate system. We have included available data on modern vertical uplift rates, including continuous Global Positioning System data from the Southern California Integrated GPS Network, Electromagnetic Distance Measurements (EDM) from the USGS, and tide gauge data from NOAA. An experimental web site has been developed to distribute the vertical uplift information to the SCEC community via a map-driven interface utilizing Arc Internet Map Server. Currently, all data can be viewed, printed, and queried through the web interface. Advanced modeling objects, allowing SCEC community members to calculate vertical uplift rates for specific terraces using user-specified sea level curves, or denudation rates with specified thermal models, and to compare long-term and recent uplift rates from multiple data sets are under development.

Data Model

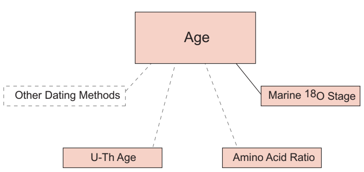


Marine Terraces

Marine terrace elevations were gathered as pilot data for developing the geologic vertical motion database. Reported terrace elevation data were obtained directly from survey measurements of different shoreline features and indirectly through extrapolation and calculation. Topographic resources, such as maps, allow for terrace elevation data where direct field measurement is not possible, and the shoreline angle can be calculated from a platform elevation point at a known distance from the sea cliff and an average platform angle elevation. In cases where shoreline angle elevations of surfaces are not reported, they are approximated and entered into the database by averaging elevations of other reported shoreline features, including sea cliffs and bedrock abrasion platforms. The terrace elevations are geographically represented in the sources by maps, which have been referenced to an online topographic database (Topozone) and given latitude and longitude coordinates for each individual entry. The resolution of terrace elevation data is within the average differences of daily mean sea level and the geographical coordinates given to each datum are within 500 meters (most within 50 meters) of the actual reported data point.

Example Marine Terrace Locality Data

Marine Terrace Name	Longitude	Latitude	Shoreline Angle Elevation (m)	Reference
Aliso Canyon 1st Bird Rock	117.448	33.272	9	Kern & Rockwell 1992
Aliso Canyon 2nd Nestor	117.4476	33.272	22	Kern & Rockwell 1992
Arroyo Honda 1st	120.1423	34.474	18	Metcalf Thesis 1994 (unpub)
Arroyo Honda 2nd	120.1422	34.474	30	Metcalf Thesis 1994 (unpub)



Marine Terrace Ages

Because great advancements in dating methods have occurred in the past 60 years, we rely to greater extent on the more recent dating results. Popular dating techniques include U-series dating of marine fossils, and aminostratigraphic and zoogeographic faunal assemblage correlation to stratigraphy, terraces, and climates of known age. Additional methods include regional elevation correlation and cosmogenic, OSL, and TL dating. Numeric terrace ages are either determined through dated fossils or correlated to known peaks of oxygen isotope stages. Each date is considered a unique data point. Besides age assignments, the assigned names, dating method and any additional data that accompanies an age determination (i.e., uranium and other isotopic concentration measurements and ratios, amino acid ratios, northern- or southern-extralimital faunal aspect) has also been included in the database for future research reference, evaluation and correlation.

Example Oxygen Isotope Stage Data

ageid	referenceid	stage	component_ageid
Cayucos 1st	Muhs et al. 1994	5e	Cayucos 1st U-Th
Point Conception 1st H	Rockwell et al. 1992	5a	Point Conception 1st H AAR
Point Conception 1st Cojo	Rockwell et al. 1992	5a	Point Conception 1st Cojo ALL
Point Conception 2nd A	Rockwell et al. 1992	5c	Point Conception 2nd A AAR

Example Amino Acid Racemization Ratio Data

ageid	referenceid	Amino Acid	ratio	error	Species
Point Conception 1st C AAR	Rockwell et al. 1992	Valine	0.65	0.01	Protothaca
Point Conception 1st C AAR	Rockwell et al. 1992	Leucine	0.32	0.03	Protothaca
San Diego 1st Bird Rock A AAR	Kern & Rockwell 1992	Valine	0.38	0.01	Protothaca
San Diego 1st Bird Rock A AAR	Kern & Rockwell 1992	D-Alloisoleucine (free)	0.25	0.02	Protothaca

Example U-Th Disequilibrium Age Data

ageid	referenceid	Age	+/-	Total U	+/-	Total Th	+/-	Isotope ratios excluded for brevity...	% aragonite	Species
Cayucos Point 1st B U-Th	Muhs et al. 1994	129	4	4.83	0.06	1.07	0.03		95	Balanophylia elegans
Cayucos Point 1st B U-Th	Muhs et al. 1994	123	3	4.95	0.06	0.29	0.02		95	Balanophylia elegans
Malibu 1st Dume U-Th	Szabo & Rosholt, 1969	112	15	0.71	0.01	0.44	0.02		0	Balanus sp.
Malibu 1st Dume U-Th	Szabo & Rosholt, 1969	101	15	2.52	0.02	0.25	0.01		98	Trachycardium quadragenarium

Marine Terrace Reference Frames

Because sea level has not been constant over time, the paleo-sea level (where sea level was relative to modern sea level in the past) for each abandoned terrace must be used to normalize terrace elevations for comparison. One of the first paleo-sea level curves was calculated from oxygen isotope records in the south Pacific, where known rates of uplift helped separate tectonic signals from the effects of volumetric changes in eustatic sea level on the coastline. These curves help predict terrace spacing along coastlines of the Pacific Ocean. The differences in terrace elevations along the California coastline do not conform to predicted terrace-spacings from southern Pacific sea level curves. The sea level curve is essential in estimating paleo-sea level along the California coastline, which, in turn, is necessary for calculating uplift rates. Thus several models of rates of change in sea level are needed to estimate the unique paleo-sea level for each terrace so that uplift rates are comparable along the southern California coastline. We have included two alternative models that we test against the terrace observations, all of which agree at the 0.1 mm/yr level

Example Paleo Sea Level Reference Frames

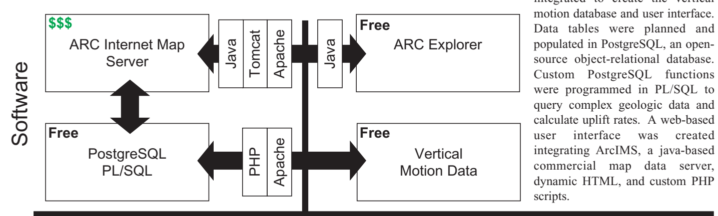
Muhs et al. 1994

Stage	Age (ka)	+/-	Sea Level (m)	+/-
5a	80	2	-6	2
5c	105	2	-8	2
5e	121	4	6	1

Chappell and Shackleton, 1986

Stage	Age (ka)	+/-	Sea Level (m)	+/-
3a	28		-44	2
3c	40		-41	4
5a	81		-19	5
5c	100		-9	3
5e	124		6	0

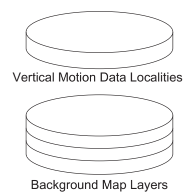
Data Processing

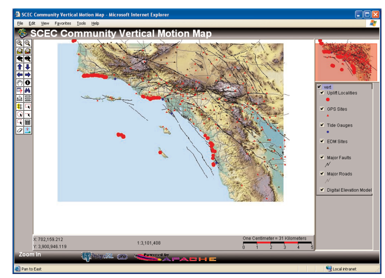


Several software components were integrated to create the vertical motion database and user interface. Data tables were planned and populated in PostgreSQL, an open-source object-relational database. Custom PostgreSQL functions were programmed in PL/SQL to query complex geologic data and calculate uplift rates. A web-based user interface was created integrating ArcIMS, a java-based commercial map data server, dynamic HTML, and custom PHP scripts.

Data Access

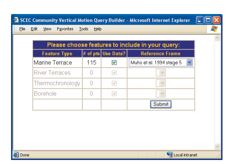
1. ArcIMS Web Service receives a request for map data from a client Arc Explorer applet (free download) or ArcGIS.



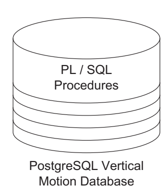


2. User browses map interface and interactively selects data.

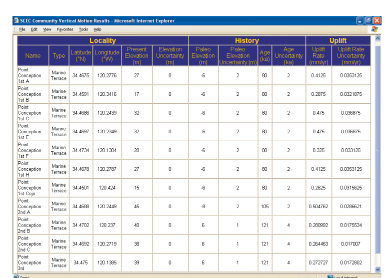
3. Selected data are queried from vertical motion data base. Data of each unique type are counted and returned to the user for inclusion or exclusion in the vertical motion output. Available reference frames for each data type are also returned



4. User marks data for inclusion in the vertical motion output and selects a reference frame for each data type.



5. Selected data, together with selected reference frames, are submitted to PL / SQL stored procedures within PostgreSQL for calculation of vertical motion rates and uncertainty. This data is returned to the user in the requested format.



6. Data and data processing information returned to the user.