### 031C-7 1040h

Detrital Ages of Himalayan (Siwalik) and Tibetan (Kailas) Molasse

T M Harrison (E&SS & IGPP, UCLA, Los Angeles CA 90024)
P Copeland (Dept. Geosci., U of Houston, Houston TX 77204)
S Burner (E&SS, UCLA, Los Angeles CA 90024)
P K Zeitler (Dept. Geol. Sci., Lehigh Univ., Bethlehem PA 18015)
J Quade (RSES, ANU, Canberra AUSTRALIA 2601)
W S F Kidd (Dept. Geol. Sci., SUNY Albany, Albany NY 12222)
T P Ojha (Geological Survey of Nepal, Kathmandu NEPAL)

Sandstones preserve a record of the unroofing history in their source areas that is often related to tectonic activity. The post-Oligocene exhumation of the Himalaya is particularly well preserved in the Siwalik Group (predominantly fluvial sandstones and siltstones) which are widespread throughout Himalayan foothills from Pakistan to eastern Nepal. $^{40}Ar/^{39}Ar$ dating of single detrital K-feldspars from three horizons from the Potwar Plateau, Pakistan ($t_{dep}$-9.4, 8.5, and 2.1 Ma), and two horizons from Bakia, Nepal ($t_{dep}$-5.5 and 2.0 Ma), provide snapshots in time of the distribution of cooling ages exposed at the Earth's surface. The minimum age in the age spectra of the 20 crystals analysed from the 9.4 Ma stratum is within analytical uncertainty (typically <0.8%) of $t_{dep}$, likely indicating exceptionally rapid unroofing in the western Himalaya. A striking aspect of the Pakistani Siwalik results is that ages between 36 and 47 Ma comprise 43% of all data (n=58). Their generally flat age spectra suggest that this population may reflect a volcanic source from late in the Andean phase of convergence (*e.g.*, Utror or Kailas) or the very rapid cooling of northern Indian margin metamorphic rocks. In contrast, 85% of the grains from the 5.5 Ma Bakia horizon (n=19) yield ages between 10 and 21 Ma - the latter age the onset of a widespread unroofing event throughout the Himalaya and southern Tibet. 73% of grains from the 2.0 Ma Bakia stratum yield ages between 60 and 700 Ma. These older grains may be derived from the Midlands Formation which was apparently not shedding detritus into the foreland basin just 3 Ma earlier. In central-southern Tibet, the Kailas (Late Eocene to Miocene?) conglomerate developed a thickness of over 4 km due to uplift and erosion of the Gangdese belt. $^{40}Ar/^{39}Ar$ age spectrum results on a K-feldspar from a cobble presumably derived from the Kailas volcanics yields an age spectrum characterized by relatively slow cooling (<8°C/Ma) between 27-19 Ma followed by very rapid cooling (60°C/Ma) between 19-18 Ma. Although the rock retains volcanic features, the feldspar microstructure indicates that it has been heated to about 500-600°C subsequent to eruption. This thermal history is consistent with deep burial in the volcanic pile subsequent to extrusion at 39 Ma followed by rapid unroofing beginning at about 20 to 19 Ma. These results suggest an upper limit of the depositional age of early Miocene.

### 031C-8 1055h

How long did it take to make the Tibetan plateau?

P Copeland (Dept. Geosci., U of Houston, Houston TX 77204)
T M Harrison (E&SS & IGPP, UCLA, Los Angeles CA 90024)
W S F Kidd (Dept. Geol. Sci., SUNY Albany, Albany NY 12222)
A Yin (E&SS, UCLA, Los Angeles CA 90024)

How long did it take to make the Tibetan plateau? Although it is certain that the India-Asia collision is responsible, and probable that the collision began at 50 to 40 Ma, the details of this process are remarkably uncertain. This problem is probably best viewed as two related questions; 1) what were the mechanisms and timing of crustal thickening, and 2) when did the plateau achieve its present extent and elevation? Differences in the timing and rate of crustal thickening predicted by simple tectonic models are most pronounced for the area forming the southern margin of Asia since the onset of the India-Asia collision about 40-50 Ma ago. Because the drainage across the Himalaya and southern Tibet is antecedent, this region would have responded rapidly to the establishment of topography at all times since collision by erosional or tectonic denudation. None of the models proposed to explain the present disposition of crust (*e.g.*, underthrusting, distributed shortening, hydraulic uplift) in Tibet predicts the prominently enhanced denudation/uplift in the early Miocene (about 21 to 18 Ma) that is suggested from thermochronologic studies near Lhasa (Gangdese belt) and elsewhere, from the ages and thickness of molasse sediments, from the erosional record seen from the detrital mineral ages in the Siwalik Group and the Bengal Fan, and other lines of evidence. Thermochronologic, paleoclimatic and plate deformation studies suggest that the present extent and elevation of the Tibetan plateau was achieved by about 8 Ma, possibly due to lithospheric delamination. We propose a model involving development of a late Oligocene-Early Miocene crustal-scale thrust ramp of the Main Central Thrust beneath the Gangdese belt (the Gangdese Thrust System) during the waning stages of crustal extrusion that had retarded thickening in central and eastern Tibet throughout the Oligocene. Once left-lateral movement on the Red River fault zone ceased in the Early Miocene, further convergence was taken up on the GTS causing rapid uplift and unroofing.

### 031C-9 1110h

A Thermochronological Perspective of Tibetan and Kunlun-Karakorum Tectonics

N O Arnaud and Ph Vidal (Both at: URA 10 CNRS, Univ. Blaise Pascal, Clermont-Ferrand 63000 FRANCE
T M Harrison (E&SS & IGPP, UCLA, Los Angeles CA 90024)

During the 1989 and 1990 Sino-French geotraverses through northern Tibet, granitoids were sampled along vertical sections in which maximum obtainable relief was utilized. These samples have been studied by $^{40}Ar/^{39}Ar$ analysis of K-feldspars and micas and fission track analysis of apatite and zircon. Calculated thermal histories from both approaches are in excellent agreement. The central Kunlun exhibits no sign of rapid unroofing subsequent to the India-Asia collision, but a brief pulse just prior to 18 Ma is documented by the rapid closure of apatites throughout the vertical profiles. Subsequently, only about 4 km of erosion has occurred. Given the presently high relief of the Kunlun, this suggests to us that much of this overburden removal is late Neogene. The western Kunlun, in the Mustagh Ata and Gongar Shan regions, exhibits rapid ongoing denudation/uplift with concordant apatite and zircon fission track ages of about 1 Ma. This is similar to that observed further to the south at Nanga Parbat. Surprisingly, west-central Tibet appears to have experienced less than about 4 km of unroofing since 60 Ma as evidenced by pre-collision ages of even apatites. These results may have a bearing on the Cenozoic tectonics of Asia, particularly the mechanisms of accommodation of the continent-continent collision. Together with several earlier studies, our data suggest that thickening in response to collision may have been forestalled until the Early Miocene, perhaps due to the effect of continental escape.

### 031C-10 1125h INVITED

**Evidence for Late Cenozoic Uplift of Mountain Ranges: Artifacts of Climate Change?**

Peter Molnar (Massachusetts Institute of Technology, Department of Earth Atmospheric and Planetary Sciences, 77 Massachusetts Ave., Cambridge, MA 02139)
Philip England (Oxford University, Department of Earth Sciences, Oxford, UK.)

Evidence of different types has been used to infer a Pliocene or Pleistocene uplift of mountain ranges throughout the world. The global distribution of mountain ranges assigned recent uplift clearly points to a global process. Inferences of recent uplift of mountain ranges assigned recent uplift clearly points to a global process. Inferences of recent uplift are commonly based on evidence for recent rapid erosion or denudation of mountain ranges and recent rapid deposition of coarse sediment near the ranges. In some cases, inferences of recent uplift are buttressed by paleobotanical observations of plants similar to those now growing in much warmer environments than those characterizing the fossil localities. We suspect that much of this evidence is severely contaminated by, if not totally caused by, climate change. Global cooling during the Cenozoic Era has surely contributed to the paleobotanical evidence used to infer recent uplift. Climate change, particularly that in late Pliocene time, may also have altered geomorphic processes so drastically as to have caused recent increases in erosion, denudation, and sedimentation in different areas, with each leading to the illogical, if geological, inference of recent uplift.

## O31D CA: 308 Wed 0830h
## Description and Modeling of NE Pacific Boundary Currents I

*Presiding:* **T Strub,** Oregon State Univ; **B Peterson,** NOAA/COAP

### 031D-1 0830h INVITED

Air/sea/land Interaction Over Coastal California with High-Resolution Limited-Area Models

W B White (Scripps Institution of Oceanography, La Jolla, CA 92093; 619-534-4826

J. Roads, A Pares-Sierra and K Ueyoshi (Scripps Institution of Oceanography, La Jolla, CA 92093

Recent descriptive and modeling studies have indicated that mesoscale eddy activity in the California Current, on a variety of time and space scales, is generated principally at or near the coast, associated with the development of upwelling fronts and coastal synoptic circulations. These eddies are found to propagate westward from the coast, entering the California Current further offshore, where they interact weakly with the meridional background flow of the California Current. The study into the dynamics of mesoscale eddy generation at or near the coast requires an oceanic model that has sufficient resolution (i.e., 10 km) to observe the ageostrophic responses to wind stress forcing at the coast, the development of upwelling fronts in the near-shore, and the instability of these fronts. It also requires that the wind stress forcing along the coast of California be modeled on a similar grid, with the influence of coastal orography and land/sea heat sources/sinks taken into account. In response to these requirements, realistic multi-layered high-resolution limited-area numerical models of both the California Current and the atmosphere above it have been developed at SIO. The high-resolution atmospheric model is nested within the operational NMC global general circulation model. Its ability to simulate Santa Anna winds and the Catalina eddy has been tested. Presently, a 1-month time sequence of high-resolution winds is being verified against winds measured at buoys located in the near-shore of the California coast. These high-resolution winds have also been used in conducting ocean model experiments. The high-resolution mesoscale ocean model consists of an entraining mixed layer embedded within an n-layer system. It is highly sensitive to high-resolution wind forcing at the coast. The response of this model to winds of varying resolution will be discussed.

### 031D-2 0850h

Variability of the Atmospheric Boundary Layer Over the Northern California Shelf During SMILE

A G Enriquez and C A Friehe (Both at: Department of Mechanical and Aerospace Engineering, University of California, Irvine, CA 92717)

The spatial and temporal variability of the boundary-layer structure over the coastal shelf off of Northern California was studied during SMILE (Shelf MIxed Layer Experiment) with an instrumented aircraft. The flights were conducted in winter 1989, with varying wind strengths and directions over the shelf caused by synoptic weather systems moving through the area. Fluxes of momentum, heat and moisture were computed from low-level fast-response flight data. Results for three different wind directions – downcoast, upcoast and on-shore – show the complexity of the boundary-layer structure and variability of the air-sea fluxes.

The downcoast wind case was similar to the previously-studied CODE summer-time situation, except that the surface layer was unstably stratified. Winds were strong, to 18 m/s, with low-level jets observed in the profiles below inversions. Variability of the surface (30m) wind stress was large, varying by a factor of 4 over the area with a region of large stresses, 0.4 to 0.5 Pa, off-shore west of Pt. Arena.

The upcoast case was characterized by a stably-stratified temperature profile with weak inversions. Low-level wind jets were observed at some locations. The surface wind speed was 10-16 m/s, with the highest speed and stress at the coast at Pt. Arena.

Winds in the third case were weak, primarily on-shore. The vertical structure was stably-stratified with the main inversion varying between 500 to 800 m over the area. Surface stress and heat fluxes were small, with larger values off-shore.

The curl of the wind stress was also estimated, and high positive values were obtained west of Point Arena for both the upcoast and downcoast cases.

### 031D-3 0905h

**Correlations of Daily Winds from Central California NDBC Meteorological Data Buoys, 1985-90**

David M. Husby (Pacific Fisheries Environmental Group, Monterey,CA 93942 ; 408-646-3311)

The network of NDBC meteorological buoys along the west coast of the U.S. provides valuable hourly observations of wind forcing in near coastal regions.These data are useful in providing real-time observations for commercial and scientific operations and for verifying numerical model outputs for the coastal boundary zone. The Minerals Management Service of the U.S. Dept. of Interior has been providing support for eight buoys along the California, Oregon and Washington coasts since the early 1980's, but will be phasing out this support in FY1991. Among these buoys are those at Cape San Martin (46028), Bodega Bay (46013), and Point Arena (46014). The wind data from buoys 46013 and 46014 have proven useful in describing the upstream wind forcing in quasi-synoptic surveys of the dynamic upwelling center near Pt. Reyes. Results of complex correlation analyses of the daily vector mean winds at these buoys with those in the Gulf of Farallones (46026), Half Moon Bay (46012) and off Monterey Bay (46042) are reported for the years 1985-90. In general the wind records are highly coherent but substantial differences in the seasonal statistics reflect the influence of mesoscale processes and local orographic effects. This implies the local wind stress curl may be important at certain locations along the central California coast.

### 031D-4 0920h

**Remote Sensing of the California Current**

P Ted Strub (College of Oceanography, Oregon State University, Corvallis, OR 97331-5503; 503-737-3015; OMNET/T.STRUB)

Those interested in observations from the California Current System can be divided into three general groups, based on their need for timeliness: 1) those engaged in operational activities, with a need for "real-time" data within the last 1-24 hours (for forecasts, commercial fishing, marine transport, coast guard search-and-rescue, recreational navigation, etc.); 2) those engaged in management of marine resources, with a need for "near-real-time" to historical data (within the past week to years); and 3) those engaged in scientific research, requiring high quality data but not necessarily in real-time. The data of interest come both from the air-sea interface (wave characteristics, wind speed and direction, momentum and heat fluxes, solar insolation) and from within the water column (currents, temperature, salinity, pressure, nutrient and biomass concentrations). The extent to which satellite and shore based remote sensing can provide these observations and meet the needs of the different users is reviewed, along with the space and time scales which can be resolved by these instruments.

### 031D-5 0935h

**Biological and Physical Sampling Needs for Meroplanktonic Species in the California Current**

L. W. Botsford (Wildlife and Fisheries Biology, University of California, Davis, CA 95616; 916-752-6169; Internet LWBOTSFORD@UCDAVIS.EDU)
T. M. Powell (Division of Environmental Studies, University of California, Davis, CA 95616; 916-752-1180) (Sponsor: AGU Member)

In the California Current, many species of fish and crustaceans are meroplanktonic with larval stages extending along thousands of km of coastline. The dynamics of these extended populations, in terms of stability, spatial coherence, and sensitivity to physical forcing, depend critically on dispersal of the larval stage through transport by ocean currents. Interannual variability in larval transport and survival, and their