031C-7 1040h

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

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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?

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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

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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?

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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

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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.

O

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

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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

Quadrature samples of the returns received at the individual transducer rows of the SeaMARC II sonar system were recorded over several terrains ranging from uniform sedimented areas in the western Barents Sea to rough topography along the Knipovich ridge, during two expeditions in the Fall 1989 and 1990. These data have been processed to derive differential phase angles from the complex acoustic data (amplitude and phase), and convert them to bathymetry. A nadir value is estimated from the first bottom detection and the nearest valid bathymetry points on port and starboard. These data are then smoothed and used to provide the time sampling necessary to produce a geometrically correct sidescan sonar image of the seafloor at a prescribed horizontal increment across track (constant pixel size). These algorithms have been designed for applications to real-time processing, and examples of the results are presented.

031B-7 0830h POSTER

New Corrections to Laboratory Velocities of Pelagic Carbonates: Where the Seismic Stratigraphers Went Wrong

R.H. Wilkens, J. Urmos, J. Marsters (SOEST, Univ. of Hawaii)
F. Bassinot (Pierre et Marie Curie, Paris)
M. Lyle (Lamont, Palisades)
L. Mayer and D. Mosher (Dalhousie, Halifax)

Ocean Drilling Program Leg 130 provided excellent well logging and laboratory density and compressional wave velocity data for a suite of nearly pure pelagic carbonates. Four Ontong-Java Plateau sites produced data from as deep as 1,000 meters below seafloor for carbonates ranging from ooze to hard limestone.

Laboratory data collected aboard the JOIDES Resolution were compared with in situ logging data. The data show that these pelagic carbonates exhibit little volumetric rebound due to recovery. The entire difference between lab and log values can be attributed to the expansion of seawater due to pressure release. This suggested that corrections to laboratory velocities based on rebound were incorrect, or at least theoretically unsound.

An emprical velocity correction curve was derived from the Leg 130 sites and applied to other ODP data. The curve fits all other data tested wherever carbonate content exceeds approximately 60%. We applied new corrections to data from DSDP Leg 85, collected without well logs. Results resolve a discrepancy in travel-time to basement between rebound corrected lab data and seismic reflection data.

O31C CA: 105 Wed 0830h
Himalayan and Tibetan Plateau Uplift I
(joint with T)

Presiding: **M Raymo**, Univ of California, B; **P Molnar**, MIT

031C-1 0830h INVITED

Evolution of the Tibetan Plateau, a Review

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The Tibetan plateau and the Greater Himalaya form the largest region of high elevation on the continents today; the area higher than 3000 m is about 2500 km, E-W, by 1300 km, N-S at its widest part; about one half the area is above 5000 m. Average crustal thickness beneath the Tibetan plateau is about 65-70 km and beneath the Greater Himalaya about 55 km. The crust consists of a collage continental, oceanic and volcanic arc fragments accreted mainly during Mesozoic time, and the formation of the Tibetan plateau and Greater Himalaya are the result of the collision of India and Eurasia about 45 ± 5 Ma and continued convergence of India with respect to Eurasia at 40 and 60 mm/yr at the west and east syntaxes respectively. Thickening of the crust beneath the Tibetan plateau and Greater Himalaya and their consequent increase in elevation has been interpreted to result from 1) underthrusting of the Indian lithosphere beneath the Tibetan plateau, 2) N-S shortening of the Tibetan plateau and Greater Himalayan crust or 3) combinations of these two. Although plate reconstructions yield about 3000 km of post collisional convergence, they do not constrain the mechanism of deformation. Interpretations by Tapponnier and his colleagues have suggested that in addition to shortening of Tibetan crust, convergence has been partially accommodated by large-scale eastward movement of crustal fragments along discrete fault zones; these movements are responsible for extension within the offshore regions of southeast Asia. In contrast, England and Houseman have suggested that the Eurasia should be modeled as a thin viscous sheet and predict homogeneous shortening and no extrusion beyond the limits of the thickened crust. There are significant differences between these interpretations, but insufficient data to test them adequately. Studies of active faulting show present partitioning of deformation, but these results are incomplete and can not be projected back beyond the late Pliocene; studies of pre-Pliocene deformation are too incomplete. Cited evidence from spores and pollen that suggest rapid uplift of 1-2 km of the Tibetan plateau during the past few million years seems questionable and E-W extension during the past few million years within parts of the Tibetan plateau has been viewed as the result of rapid recent uplift, but may be due to other causes. Our studies along the eastern margin of the Tibetan plateau suggest a complex evolution that does not fit any existing model, but supports limited eastward movement of crustal fragments from Tibet and absorbtion of that movement within the eastern part of the Tibetan plateau (see Burchfiel et al., this symposium).

031C-2 0850h INVITED

Development of surface height in Asia during Tertiary time.

Philip England (University of Oxford, Department of Earth Sciences, Parks Road, Oxford, OX1 3PR,

Crustal thickening in the India-Asia collision zone has caused surface uplift since early Tertiary time. There are, however, few quantitative data on this surface height history, so simple physical models provide important constraints on elevation history at the scale of interest for climatic modelling. The principal tectonic hypotheses for the origin of the Tibetan plateau are: thrusting of undeformed India beneath Eurasia, distributed deformation of the continental lithosphere of Asia, and distributed shortening accompanied, or followed by, convective removal of the lower lithosphere. The first hypothesis predicts the growth of a plateau of roughly constant elevation, with increasing area. The second predicts a plateau whose area increases somewhat with time but whose elevation increases steadily from the start of deformation to the present. The third hypothesis carries the possibility of an increase of surface height by 1 km or more during late Tertiary time. The following points should also be noted. The present Himalaya have the same average elevation as the Tibetan plateau, yet have peak heights 2-3 km above the average elevation, whereas the plateau is much smoother. The generation of this *relief* is almost certainly an erosional, not a tectonic, phenomenon. Secondly, it seems probable that an Andean-type margin of appreciable surface height existed in the region *before* the collision of India with Asia in early Tertiary time.

031C-3 0910h

Topographic Relief of the Tibetan Plateau and Surface Deformation

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Medium-resolution digital topography (~100 m grid) for most of the 4.8 km mean elevation Tibetan plateau provides valuable new information to characterize the physiography. We use computer visualization of the topography combined with analysis of relief as a function of wavelength to distinguish erosional and tectonic topographic features. The spatial variation of relief at different wavelengths is calculated by finding the difference between the maximum and minimum elevation within moving windows of various sizes. We focus here on the vast interior of the plateau away from the high relief edges. The arid to semi-arid central and northern part of the plateau interior has very low relief (average relief about 300 m computed with 10 km windows and about 100 m with 2 km windows). Significantly, the older suture zones of the plateau (Kunlun, Jinsha, and Banggong) where major thrusting occurred in the past are now low relief valleys. The only faults that manifest significant topographic relief are the relatively small-scale graben systems primarily in southern Tibet, the Indus-Zangbo suture zone and the Karakoram strike-slip fault at the south of Tibet, and the Kun Lun and Altyn Tagh strike-slip faults at the north edge of Tibet. We conclude that either *(1)* there is little deformation (especially shortening) of the uppermost crust north of the graben systems during the late Cenozoic, which is consistent with the reported lack of deformation of Pliocene and younger strata on the plateau, or *(2)* shallow crustal isostatic compensation produces low relief despite young deformation of a thin upper crustal layer.

031C-4 0925h

Geology of the Northeastern and Eastern parts of the Tibetan Plateau and its Constraints on the Evolution of the Tibetan Plateau

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Geology of the northeastern and eastern part of the Tibetan plateau indicates this part of the plateau has grown by shortening accompanied by lateral movement of crustal fragments that is mostly if not entirely absorbed along the margins of the plateau. Presently active strike-slip faults are part of the very youngest history of the plateau and can not be projected back beyond the last few million years. The northeastern and eastern part of the Tibetan plateau can be divided into 5 segments (from south to north): the southern, the Yunnan, the western Sichuan, the Qinling, and Qilian Shan-NingXia segments. Different segments developed different sequences of structural events, although within each segment only relative sequences of deformational events can be constructed because of the lack of dated rock units. Deformational events overlap temporally and may occur contemporaneously. In the southern segment events are (from oldest to youngest) 1) S to SW directed thrusting along an old Triassic suture accompanied by possible left-slip, 2) clockwise rotation of these structures and change to a right-slip regime locally associated with SE extension. In the Yunnan segment: 1) SE, E, and NE shortening extending into the basement rocks of the Yangtze platform, 2) rapid movement to the SE of this segment bounded by left- and right-slip faults on both boundaries. In the western Sichuan segment: 1) NE shortening refolding older structures, 2) SE to E shortening partly localized by the Yangtze basement and 3) right-slip faulting along NE trending faults. In the Qinling segment: 1) N-S shortenings along an older plate boundary, 2) both right-and left-slip faulting, 3) beginning development of a N-S seismic belt. In the Qilian Shan-NingXia segment: 1) NE shortening and associated clockwise rotation and left-slip faulting. Deformation in this latter segment is late Neogene and hence has not developed long enough to show a sequence of events. Geology of the northeastern and eastern parts of the Tibetan Plateau suggests that this part of the plateau has been formed by a complex sequence of events in which old crustal anisotropy has played an important role.

031C-5 0940h

Postcollision Sediments in the Bay of Bengal

Joseph R. Curray (Scripps Institution of Oceanography, UCSD, La Jolla, CA 92093-0215)

Reinterpretation of geophysical data from the Bay of Bengal suggests that total sediment thicknesses are greater than previously believed and exceed 22 km beneath the Bangladesh continental shelf. By long range correlation from an early Eocene hiatus in DSDP and ODP sites on the northern Ninetyeast Ridge, through seismic reflection stratigraphy, and into a network of seismic refraction lines, this section is subdivided into a pre-Eocene sequence that pre-dates the India-Asia collision and a post-Paleocene, postcollision part. The precollision sediments below about 16 km are believed from velocities and densities appropriate for their velocities and for isostatic balance to be greenschist facies rocks. The postcollision sediments, which exceed 16 km in thickness beneath the Bangladesh continental shelf, include the Bengal Fan, which started prograding southward following the collision, and most of the filling of the Bengal Basin. Some of these rocks crop out in the accretionary prism in the Indo-Burman Ranges in Myanmar and in the Andaman and Nicobar Islands.

Total mass of the postcollision sediments, not including those in the accretionary prism, calculated from isopachs and an assumed density profile is about 2.9×10^{16} tons. An average sediment accumulation rate for 55 my would be about 5.2×10^8 tons/yr, derived mainly from the Himalayas and Tibet through the Ganges-Brahmaputra drainage system. The present contribution from this source may be as high as 1.7×10^9 tons/yr. Rates of sediment influx were probably lower in the Paleogene and started increasing in early Miocene during rapid uplift of Tibet and the Himalayas. Several models of denudation rates and growth of the Bengal Fan will be considered.

031C-6 1025h

Himalayan Uplift as Deduced From the Stratigraphic Record

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Recent studies utilizing single-crystal dates (e.g., Cerveny et al, 1988) have shown that rapid uplift (>1-2 km/my) has occurred within the Himalaya for the past 20 my. A key question is whether this rapid uplift is widespread or whether it represents isolated areas of locally rapid uplift. Although single-crystal dating of detrital minerals is generally incapable of drawing this distinction, the regional subsidence record from the adjacent foreland can serve to clarify the nature of the uplift. Isolated rapid uplifts (like Nanga Parbat in Pleistocene times) should have little impact on the regional subsidence history, whereas range-scale uplifts should produce a distinctive signature. Based on a comparison of more than 20 magnetostratigraphically dated sections, a regional subsidence history has been synthesized for the northwestern Himalayan foreland basin. The most pronounced increase in regional subsidence during the past 15 my occurs at ~11 Ma and coincides with a marked increase in sandstone abundance and an influx of detrital hornblende. This interval is interpreted to correspond to a major crustal loading/uplift event in the hinterland. The rate of subsidence in the foreland more than doubled, and the ancestral Indus River was apparently captured by or diverted into the Ganges drainage at this time. Subsidence decelerates after 9 Ma prior to accelerating again at 4-5 Ma. This latter pulse of subsidence appears to represent initial thrusting along the MBT, uplift of the Pir Panjal Range, and creation of the Kashmir intermontane basin. Stratigraphic data indicate that at least 1 km of additional basement uplift occurred after 0.5 Ma, although the mean elevation of the land surface only increased a small fraction of this amount. Other foreland uplifts, such as in the Salt Range, appear to have caused little additional subsidence due to rapid erosion of their hanging walls.

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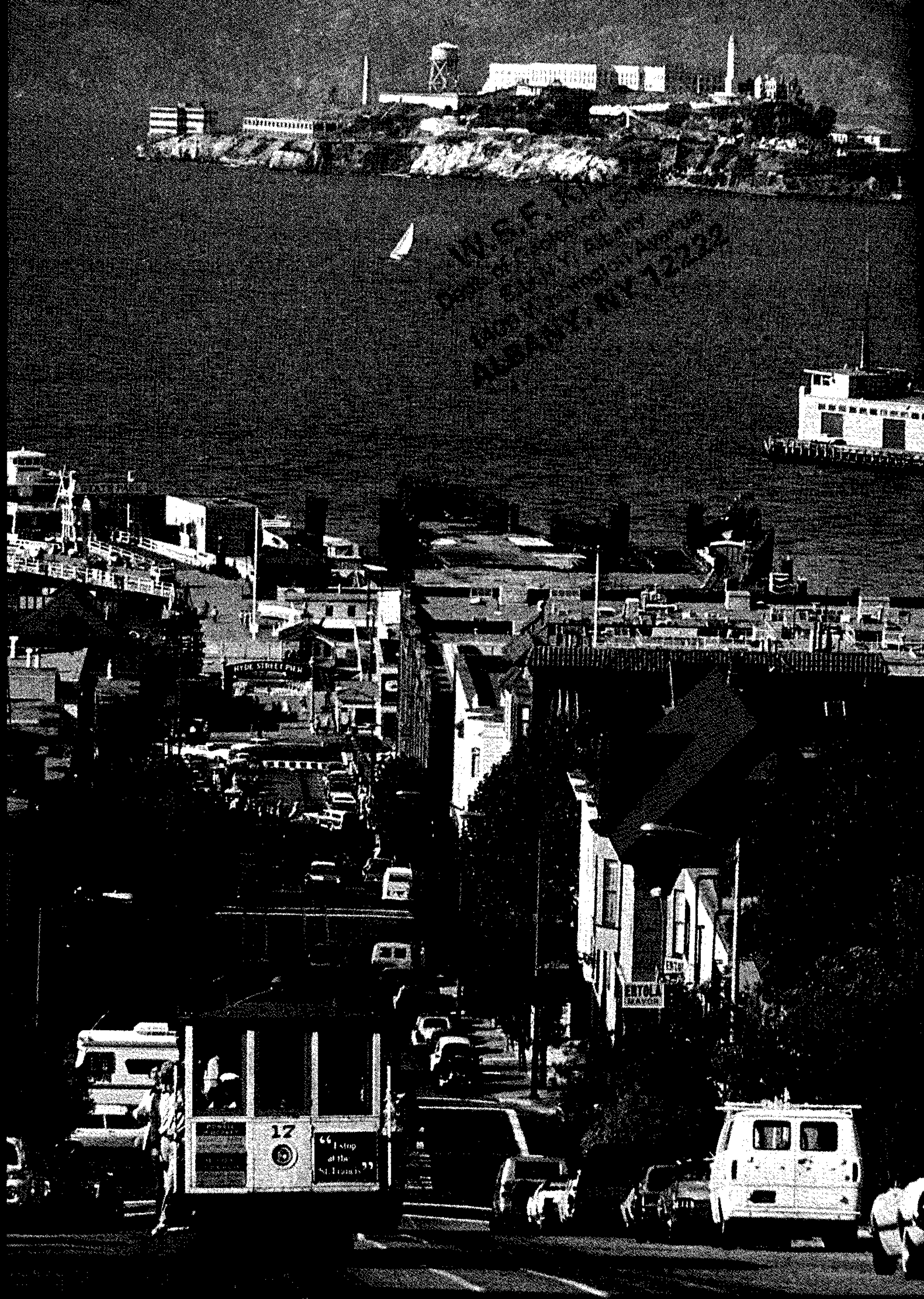

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