They found two distinct thermal events M1 and M2. Recent data for sedimentation age and thickness from ODP Leg 116 (Amano and Tairo, 1992) provided constraints on the timing of episodic denudation of the Himalayas. Based on the observational data, we carried out numerical modeling of the P-T-t paths of metamorphic rocks in the High Himalaya. It is found that, to fit the observations, the acceptable model parameters are limited to a finite range.

Event M1 is believed to result from thrust thickening of the crust followed by denudation. Results of numerical modeling suggest that the thrust event occurred about 29-24Ma, bringing the sampled rocks to a depth of 35km; denudation thereafter occurred at a rate of 1.8mm/a. Although frictional/shear heating may be important for anatexis in the region, at the sample sites, frictional heating during the thrust event is found negligible. This is in agreement with geological observations near the sites.

Event M2 is suggested to be due to intrusion of granites by Hodges et al.(1988). Results of modeling indicate that the intrusion occurred at about 12-11Ma at 10km depth; the total thickness of intrusion may reach 6km, producing high T/P metamorphism. Although the average denudation rate is 1.8mm/a, it could be as high as 3mm/a between 11-8Ma after the intrusion.

Hodges et al. (1988) also proposed high radiogenic content of shallow crust as an alterative interpretation for event M2. we find the required radiogenic content would be as least 50 times greater than the average value. Therefore, this alterative could be rejected.

T32D-7 1515h

Rb-Sr Microchrons in the Manaslu Granite: Implications for Himalayan Thermochronology

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The uplift and erosional history of the Himalaya is of interest because of its potential effect on global climate as well as for documenting the details of one of the earth's largest continental collisional events. Isotopic studies of the granitic rocks of the Himalaya have been pursued in the hope of better defining both the timing of uplift and the time of generation of the granitic magmas. Difficulties are encountered with the Rb-Sr and U-Pb systems because of heterogeneity and inherited components (Deniel et al., Contr. Min. Pet. 96, 78, 1987).

To help clarify the chronology, we made Rb-Sr measurements on texturally controlled microsamples of Manaslu Granite minerals from two rock samples obtained from P. LeFort. Samples are portions of muscovite, biotite, feldspar and tourmaline, each between 90 and 300µg mass, with inter-sample distances of 0.3 to 1mm.

Sample X-12 from the main granite body gives a Muscovite-Feldspar age of 19.19 Ma, with an initial $^{87}Sr/^{86}Sr$ = 0.758. In the same sample, a 300µm-thick biotite and surrounding muscovite give an age of 16.45 Ma. The biotite-feldspar age of 16.66 Ma is ficititous because after "closure" of the muscovite, the embedded biotite could only have equilibrated with the surrounding muscovite.

Sample H-227, a high-Rb/Sr dike from the Chhokang Arm, gives a Muscovite-Feldspar age of 17.54 Ma, with higher initial $^{87}Sr/^{86}Sr$ = 0.767 (also the value for the whole rock at 17.54 Ma). Tourmaline from H-227, within 2mm distance of feldspar, has $^{87}Sr/^{86}Sr$ = 0.757. The minerals other than tourmaline were apparently kept in isotopic equilibrium until ca. 18 Ma. The whole rock - tourmaline age is 29 Ma, which could be the original magmatic age.

Our results indicate very rapid cooling, presumably a result of unroofing, between 19.2 and 16.5 Ma. Using traditional closure temperatures and 30°C/km gradient, the unroofing rate could have been 2.5mm/yr, about 3 times the estimate for 21 to 13 Ma period (Deniel et al., 1987); this timing correlates well with the period of rapid erosion inferred from Sr isotopes in seawater (Richter et al., EPSL, 1992). The results also support an Oligocene magmatic age, which appears to be required by U-Pb data (Deniel et al., 1987).

T32D-8 1530h

Geophysics and geochemistry of the Siwalik Group, Nepal: Implications for the rates and scale of tectonism in the central Himalaya and the onset of the Asian Monsoon.

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The post-Oligocene exhumation of the Himalaya is particularly well preserved in the molasse deposits of the Siwalik Group (predominantly fluvial sandstones and siltstones) which are widespread throughout the foothills of the Himalaya from Pakistan to Sikkim. These rocks can be directly correlated with tectonic activity in the highlands, reflecting times of local deformation, and contain information about the pre-depositional history of the detritus and the ecology of the flood plain in which the sediments were deposited. Magnetostratigraphic data are now available from two sections of Siwaliks in Nepal: a 2600 m-thick section at Bakiya Khola in east-central Nepal (this study) and a 3700 m-thick section at Surai Khola in west-central Nepal, some 250 km to the west (Appel *et al.*, 1991). Preliminary analysis of 93 samples from the Bakiya section, by thermal demagnetization, suggests that the 2550 m measured at Bakiya Khola were deposited between 9.85 and 6.25 Ma. $^{40}Ar/^{39}Ar$ dating of 91 detrital K-feldspars from six horizons in the Bakiya Khola section (t_{dep} = 8.38 to 6.67 Ma), provide snapshots in time of the distribution of cooling ages exposed at the Earth's surface. The minimum age in the spectra from five of the six horizons averages only three million years older than t_{dep} indicating exceptionally rapid unroofing in the Himalaya throughout that interval. 65% of the fifty-nine grains from the three youngest horizons (6.67, 6.82, and 7.06 Ma) in the Bakiya section yield minimum ages between 7 and 21 Ma. This latter age corresponds to the onset of a widespread unroofing event throughout the Himalaya and southern Tibet. Sediment accumulation rates, calculated from the paleomagnetic data at both Bakiya and Surai Kholas, vary from 0.1 mm/year to at least 2.0 mm/year. The history of accumulation shows a distinctly variable pattern characterized by rapid increases in rate followed by a more gradual decrease that is repeated on the time scale of ~0.3 to 1.5 million years. Initial analyses from Bakiya Khola indicate broad correlations between intrinsic and induced rock magnetic properties and accumulation rate, suggesting that remanence characteristics reflect depositional histories. Stratigraphic variations in ratios of rare earth elements, notably Ce/Yb and La/Sc, indicate changes in provenance that are also correlated with accumulation rate.

Carbonates in paleosols exposed along Bakiya Khola yield carbon isotopic values averaging -10.5‰ $\delta^{13}C$ between 9.8 and 7.4 Ma, and about 0‰ $\delta^{13}C$ between 7.4 Ma to the top of the section at about 6.3 Ma. This shift was previously recognized in Siwalik Group sediments in Pakistan and is interpreted to result from a change from dominantly C_3 plants (*i.e.*, trees) to dominantly C_4 plants (*i.e.*, grasses). The first appearance of C_4 grasses favored by a warm growing season marks a significant ecological shift that may be related to intensification of the Asian Monsoon brought about by uplift of the Tibetan Plateau. For the time interval preserved at both Bakiya and Surai Kholas (9.8 to 6.3 Ma), the rates of sediment accumulation show a remarkably similar pattern (in both the time and magnitude of the changes), considering the distance separating these two sections. Similar accumulation rate patterns can also be observed in Siwaliks in Pakistan suggesting that such patterns may represent a widespread phenomenon. While variations in climate could explain changes in sediment delivery rate to the foreland over a large area, several lines of evidence argue against this. These data therefore suggest a heretofore unrecognized scale of tectonics in the Himalaya during the Miocene.

T32D-9 1545h

The Gangdese Thrust Revealed

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It has long been appreciated that a portion of the convergence in the Indo-Asian collision has been accommodated by major intra-continental thrusts in the Himalaya, e.g., the MCT and MBT. On the basis of thermochronological results and geologic relationships, in particular the juxtaposition of Indian continental margin deposits (Tethyan) against the Andean-type plutonic belt (the Gangdese Batholith) we earlier postulated the existence of a south-directed intra-continental thrust system in southern Tibet, the Gangdese Thrust System (GTS).

Field observations and paleo-unroofing studies indicate a clear negative correlation between the preservation of forearc sediments (Xigaze Group) and the magnitude of exhumation. West of Rinbung (90°E, 29°N) the style of deformation in the hanging wall of the GTS is characterized by south vergent thrusts and folds along the southern portion of the Xigaze Group and north vergent thrusts and folds along its northern margin. East of Rinbung crustal shortening is concentrated along the north-dipping GTS which brings Gangdese plutonics directly over the Tethyan sedimentary rocks eliminating exposure of the forearc sediments. Near Xetang (92°E, 29°N) in the easternmost observed portion of the GTS the fault zone is characterized by the presence of several hundred meters of mylonitized granite and sedimentary rocks. In contrast, the GT near Xigaze is characterized by cataclastic deformation

Excellent exposures of the GT east of Xetang contain abundant kineamatic indicators, e.g., asymmetric folds, asymmetric boudinage and minor south-directed thrusts, that unambiguously demonstrate the south-directed nature of the thrust which currently dips ~35° to the north. Directly below the mylonitic shear zone of the GT is a sequence of unmetamorphosed conglomerates (> 1 km). The conglomerate cobbles are predominantly marble, but also contain rare cobbles of Gangdese plutonics. The failure to previous recognize this important structure is largely due to the presence of a younger north-directed thrust system, the Rinbung-Xetang Thrust (RZT), which truncates the GT obscuring its trace and in at least one locale juxtaposes Tethyan rocks over unconsolidated gravels.

On the basis of our existing thermochronological results we infer that significant motion along the GTS occurred between 25-18 Ma. The geological relationships characterizing the rocks east of Xetang are also shared by those in the vicinity of Mt Kailas, ~1100 km to the west, where we have also documented early Miocene uplift. This suggests that the GTS was active over at least 1100 km. Absence of the Xigaze group implies a minimum displacement of ~20 km along the GT. This crustal thickening event explains the rapid unroofing of an equivalent section in the eastern Gangdese. This precludes other mechanisms (climate change, tectonic denudation) as the primary cause of the early Miocene transition in cooling rate. The variation in the magnitude of displacement along the strike of the GT may be due to the transfer of displacement to thrusts in the Tethyan Himalaya, irregularity of the northern boundary of the Indian continent, or mismatch of curvature of the Gangdese arc and the Indian continent.

T32D-10 1600h

Thrust Sequence Within the Western Sierras Marginales Thrust Sheet, South-Central Pyrenees, Spain

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Late Eocene-Oligocene deformation related to the emplacement and dismemberment of the Sierras Marginales thrust sheet involved a complex sequence of thrusting in space and time. This study, in the region around the Ribagorzana River, focuses on the southern, frontal portion of the Sierras Marginales thrust sheet which consists of a series of imbricate thrusts whose latest motion occurred in a clear break-back thrust sequence. This motion occurred on pre-existing faults, a number of which show clear evidence of Early Eocene motion. Major structures consist of laterally continuous thrust sheets comprising northeastward-thickening Triassic-Paleocene passive margin and Lower Eocene marine and Upper Eocene-Oligocene non-marine syntectonic deposits.

The Upper Eocene-Oligocene syntectonic deposits, represented by three unconformity-bounded packages, are best exposed in a major structural low, the Baldellou syncline. The southerly, more forelandward, structures occur in the stratigraphically lower units which onlap the southwest limb of the syncline. This continuous succession grades from evaporitic-lacustrine deposits to fine-grained fluvial deposits. A hangingwall-derived conglomerate unconformably overlies and fossilizes structures developed in the lower stratigraphic unit. It locally onlaps and is folded by reactivated structures. A regionally extensive clastic sequence unconformably overlies the lower two units and is gently warped into broad folds. The youngest thrust cuts this highest stratigraphic unit. A fundamental change in the wavelength and amplitude of major structures occurs in the hangingwall of this thrust. Its structural position is correlative with a regionally developed zone of out-of-sequence thrusts.

T32D-11 1615h

Emergence of the External Sierras, SW Pyrenees: Chronology and Sedimentary Response

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The External Sierras separate the Jaca and Ebro basins and form the youngest south Pyrenean frontal thrust complex. Clearly exposed cross-cutting relationships between five hindwards-imbricating thrust sheets and eight conglomeratic packages document the deformational and depositional history of this area. Located along the S margin of the range, three new magnetostratigraphic sections span ~15 m.y. and serve to calibrate three Oligocene-aged episodes of thrusting. These temporal data indicate that the San Felices thrust sheet was emplaced between 35.0 and 32.4 Ma, the Punta Común thrust sheet moved between ~32.4 and 31.0 Ma, translation and imbrication of the Riglos thrust sheet occurred between 26.4 and 24.4 Ma, and the final largely post-tectonic phase of conglomeratic sediments were probably deposited in late Chattian or early Aquitanian times. Based on balanced and restored sections, shortening rates for these tectonic events range from ~1.2-2.7 mm/yr. Whereas rates of shortening *decrease* through time, rates of bedrock uplift and erosion *increase* over this same interval. This is attributable to the style of shortening, whereby initial shortening was accommodated by thrust ramping and southward translation, whereas subsequent shortening resulted in breakback thrusting, folding, and thickening of the orogenic wedge.

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T32D-12 1630h

Progressive Unconformities: A key to Understanding Fold-and-Thrust Evolution

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Descriptions of syntectonic sediments showing progressive unconformities (wedge-shaped geometries adjacent to growing structures) are uncommon in the geological literature. Riba (1976) interpreted these geometries as an interplay between rates of tectonic uplift and rates of accumulation in one or both flanks of the structure.

Syntectonic sediments often provide the tighest constraints on tectonic activity in a specific structure because they record the sequential evolution of the fold or thrust. Complete and partial restorations of detailed corss-sections facilitate the understanding of the kinematics of adjacent folds and thrusts.

Examples of progressive unconformities from the southern Pyrenees include 1) syntectonic sediments deposited on previous paleorelief which is deformed synchronously with ongoing deposition, and 2) syntectonic sediments deposited on newly

We are in the early stages of applying these techniques to the Manus Basin, Papua New Guinea. This basin, like other SW Pacific backarc basins which are actively spreading, has had a complex history including ridge jumps, microplate development and propagation of spreading into areas of island arc crust (4). These complexities severly constrain the lateral extent of bathymetric features. This is like the situation at very fast ocean-ridge spreading centres where preliminary results (2) show unusual relationships between geological and stochastic parameters.

The first step in any statistical anylasis is to define objectively homogeneous data sets, in our case areas with similar morphological features. Initially, these areas will be defined on the basis of fractal parameters (roughness) and slope gradients calculated from SeaMARC II vertical beam data. Subsequently, these definitions will be refined by analyzing a gridded data (100m bins) derived from SeaMARC II swath bathymetry. Our ultimate aims are to explore the extent to which these and other characteristic morphometric parameters can be used as aids in interpreting the complex tectonic history of this and other backarc basins. Examples of analytical results and problems will be discussed.

!. Goff, J A & Jordan, T H (1991) *JGR* 96B, 3867-3885; 2 Goff, J A (1991) JGR 96B, 21,713-21,737; 3: Goff, J A (1992) JGR 97B, 9183-9202; 4. Taylor, B et al., (1986) Eos 67, 377, 1228; (1987) Eos, 68 1476; (1991) *Pacific Seafloor Atlas*, Hawaii Institute of Geophysics, Sheets 1-7.

T32D CA: 317 Wed 1330h

Alpine-Himalaya Collision Zone *(joint with S)*

Presiding: **S Klemperer,** Stanford Univ; **D Burbank,** Univ of S. California

T32D-1 1330h

International Deep Profiling of Tibet and the Himalaya (INDEPTH): Origins of the Sino-U.S. Pilot Survey

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"Clearly , detailed seismic reflection, wide-angle reflection and refraction work is needed" - American Plate Tectonics Delegation to Tibet, 1982.

As the archetype continent-continent collision, the Himalaya and Tibetan Plateau have long been a prime candidate for deep seismic reflection profiling. Although the logistical challenges of operating a modern seismic reflection crew in such a remote and difficult area were perceived as daunting, discussions between Chinese and foreign scientists concerning a deep reflection transect across the entire collision zone go back a decade. Serious consideration began with an informal discussion convened by Jack Oliver during the Second International Symposium on Deep Seismic Reflection Profiling held in Cambridge, England, in 1986. A dialogue with the Chinese Ministry of Geology and Mineral Resources (MGMR) concerning a trans-Tibetan profile was begun at the IUGG Meeting in Vancouver in 1987 and continued via the 1988 Canberra symposium on Deep Seismics and the 1989 International Geological Congress in Washington, D.C. Initial scouting of south-central Tibet by an international delegation of crustal seismologists in October, 1987, was followed by a proposal from a team of scientists from several U.S. universities to the National Science Foundation to fund, jointly with the MGMR, a Sino-U.S. pilot effort. The Chinese Academy of Geological Sciences (CAGS) of the MGMR and Cornell University agreed to serve as joint operating institutions. Negotiations between the MGMR and U.S. scientists in October 1991 and May 1992 finalized details of the test survey, which expanded to include an NSF-funded program of auxiliary geophysical measurements under the direction of scientists from Stanford University. A test local in the Tethyan Himalaya of southernmost Tibet was selected as most likely to yield interpretable initial results on issues of fundamental geological importance, including a possible traverse of one or more of the striking Moho offsets suggested by the seminal Sino-French wide-angle experiments of 1981. Field work for Project INDEPTH began on June 20 and ended on August 16, 1992.

Analysis of the results is now being carried out jointly by Chinese and U.S. scientists. Initial findings, described in the following reports, clearly indicate that deep seismic reflection profiling can effectively probe the unusually thick crust of Tibet. Equally important, U.S. and Chinese scientists established the working relationship necessary to mount a grand geoscience initiative like Project INDEPTH. Planning for the next phase of the full Tibetan transect is underway.

T32D-2 1345h

First Deep Seismic Reflection Profile in the Himalaya/Tibet Plateau: Initial Results of Project INDEPTH

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The pilot phase of a planned multi-year program to collect deep seismic reflection data across the Himalaya/Tibet plateau collision zone was undertaken this past summer by a team of scientists from China's Ministry of Geology and Mineral Resources (MGMR) and several U.S. universities. Project INDEPTH (INternational DEep Profiling of Tibet and the Himalaya), collected approximately 100 km of CMP deep reflection data along a NNE trending mainline and short crossline within the Yadong-Gulu rift in the Tethyan Himalaya south of Kangmar. The goals of the pilot study where to test the feasibility of CMP deep profiling in the harsh conditions of the plateau and examine crustal structure beneath the north flank of the Himalaya.

Although processing of the reflection data is preliminary, several substantial observations are already evident. 1) A prominent gently north-dipping reflection extends across the entire profile at 10-11.5 s twt (about 30 to 35 km depth), and is tentatively interpreted as marking the present detachment between the Asian and Indian plates beneath southern Tibet - substantially extending the "known" northward extent of this fundamental structure. 2) Several prominent bands of reflections observed on the southern part of the profile occur within the appropriate travel-time range to originate from the base of the roughly double thickness crust underlying southern Tibet (23-26 s, about 70-75 km depth), and are likely the deepest Moho reflections ever observed on a CMP reflection profile. 3) A number of upper crustal reflections (< 10 s twt) are also observed that should provide information on the geometry of the Yadong-Gulu rift, its bounding fault, and perhaps the South Tibetan Detachment. These early results confirm that CMP profiling using modest charge sizes and conventional recording systems can be used effectively to image structure throughout the very thick crust of the Tibet plateau.

T32D-3 1400h

Deep Seismic Profiling in the Himalaya: Acquisition and Field Processing of Reflection Data for Project INDEPTH

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An explicit goal of Project INDEPTH was to evaluate multichannel reflection equipment and techniques in the harsh Tibetan environment. Among the key issues to be addressed were the logistics of mobilizing and maintaining a seismic reflection crew at such a remote site, the efficacy of drilling shotholes in the variable and difficult near-surface geology of southern Tibet, the source requirements for penetrating the extremely thick Tibetan crust, integration of CDP profiling with wide-angle and "3-D" auxiliary experiments and establishing effective communication among a multi-lingual technical directorate.

INDEPTH-1 is an approximately 100 km long survey following three extensional NS basins and intervening highs. along with 8 km long EW cross-line. Reflection profiling was carried out by the Fifth Geophysical Brigade of the MGMR (PRC) using a 120 channel DFS V recording to 50 s. Nominal 50 kg charges were shot every 200 m into a 6 km long spread with a 50 m geophone spacing. Additional shots of 200 kg were used at 6 km intervals. Nearest source-receiver offsets were typically 200 m and 4000 m for the 50 kg and 200 kg shots respectively.

Drilling was a problem because of the highly variable surface geology, including alluvial sands, gravels, and boulders. The target hole depth of 50 m was difficult to achieve; average hole depth was only 25 m. Deep holes were almost always better than arrays of shallow holes. In general, 200 kg shots yielded more deep energy than the 50 kg shots, but well-placed small shots sometimes gave better results than some big shots. Tests of various charge sizes and depths confirmed, however, that deeper holes and larger charges were more effective.

Field processing proved to be essential in monitoring data quality and modifying the field program. The system consisted of a DECstation 3100 running ProMAX (Advance Geophysical Corp.) interactive processing software powered by an 8 KVA Dayton gasoline generator conditioned by American Power Systems UPS units. DFS V 9-track tapes were demultiplexed on a StorageTek drive and archived to 8 mm Exabyte tape. Field processing included velocity analysis, frequency filtering, FK filtering, mute, statics, and brute stack.

For future work, tri-cone bits, drilling muds, and casing should be considered. Procedures for mitigating the noise effects of high afternoon winds and cable cross-talk resulting from frequent monsoon thunderstorms should also be implemented. In spite of these problems, the INDEPTH pilot effort demonstrated that "conventional" profiling can be quite effective in probing even the world's thickest crust.

T32D-4 1415h

INternational DEep Profiling of Tibet and the Himalaya: piggyback recording to complement the near-vertical seismic reflection profile.

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Zhao Wen-Jin, Che Jing-Kai, Liu Xian-Wen, Guo Jing-Ru, Wu Chang-De (Chinese Ministry of Geology & Mineral Resources); and the INDEPTH Working Group.

The test phase of Project INDEPTH recorded 100 km of deep seismic reflection profile in southern Tibet in summer 1992 (companion abstract by Nelson et al.). To test the feasibility of piggyback experiments in Tibet, PASSCAL Refteks were deployed in a variety of geometries to record the seismic sources: 50 kg charges at nominal 200 m spacing and 200 kg charges at nominal 6 km spacing. We will present preliminary results from these experimental deployments.

Five sites with 4.5 Hz three-component geophones were deployed within and off-end the reflection profile, for wide-angle coverage of offsets from 0 to 150 km. These sites also included additional Refteks to record arrays for stacking and beam-steering, and 5-second sensors deployed on bedrock for low-frequency recording. Although the 50 kg shots produced very variable energy, many 50 kg shots are clearly visible before stacking at offsets to greater than 100 km.

One Reftek was deployed close to each source-point to record a single-fold three-component near-vertical profile coincident with the main 15-fold P-wave reflection profile. Refteks were deployed at six sites broadside to the main seismic profile to provide 3-D control on structures imaged by the main profile. Chinese scientists also made gravity and magnetic measurements at 200 m intervals along the main reflection profile.

T32D-5 1430h

A Tectonic Model for the Kumaon-Garhwal Lesser Himalayas (India) Based on Balanced Cross-sections, Branch Line Maps, and Geothermobarometry.

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The Kumaon-Garhwal region lies near the center of the Himalayan fold-and-thrust belt and is thus a critical area for studying typical Himalayan structures. Our recent structural and thermobarometric studies in this area have led to a model consistent with modern thrust tectonics concepts. The regional structure is reinterpreted and new structures have been recognized. The deep structure of the Kumaon-Garhwal Himalayas is constrained based on two parallel balanced cross-sections, drawn approximately 100 km apart, and incorporating surface, earthquake seismic, and well log (from foreland) data. Branch line maps were constructed from surface branching patterns of thrust traces as well as projections of buried branch lines in order to understand the 3-dimensional structure of the region. These studies show that the thrust belt is underlain by a regional basal detachment (depth: 18-22 km) at the basement-cover contact, into which the major thrusts (e.g. Main Central thrust, MCT; Munsiari thrust; Main Boundary thrust) merge. A buried duplex involving Precambrian sedimentary rocks lies under the Lesser Himalayas, carrying the rocks exposed at the surface as a roof thrust sheet.

Structural and thermobarometric evidence suggests that the metamorphic klippes of the Kumaon-Garhwal Himalayas are derived from the Munsiari thrust sheet, and not from the MCT sheet as was previously thought. Unlike the Lesser Himalayas of Nepal, the MCT sheet was not emplaced in Kumaon-Garhwal, instead the Munsiari thrust took over a part of the total shortening in this area. Thus, there is a large variation (~80 km) in displacement along the strike of the MCT, which had not been realized until now. The total tectonic shortening calculated for the Kumaon-Garhwal Himalayas from the balanced cross-sections, between the Indo-Ganga foreland and the Indus-Tsangpo Suture, varies from 78% to 82%, which is higher than the values reported from other parts of the thrust belt.

T32D-6 1445h

Thermal Modeling of P-T-t Paths in the High Himalaya

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Hodges et al. (1988) published P-T paths for the High Himalayan metamorphic rocks north to the Main Central Thrust.

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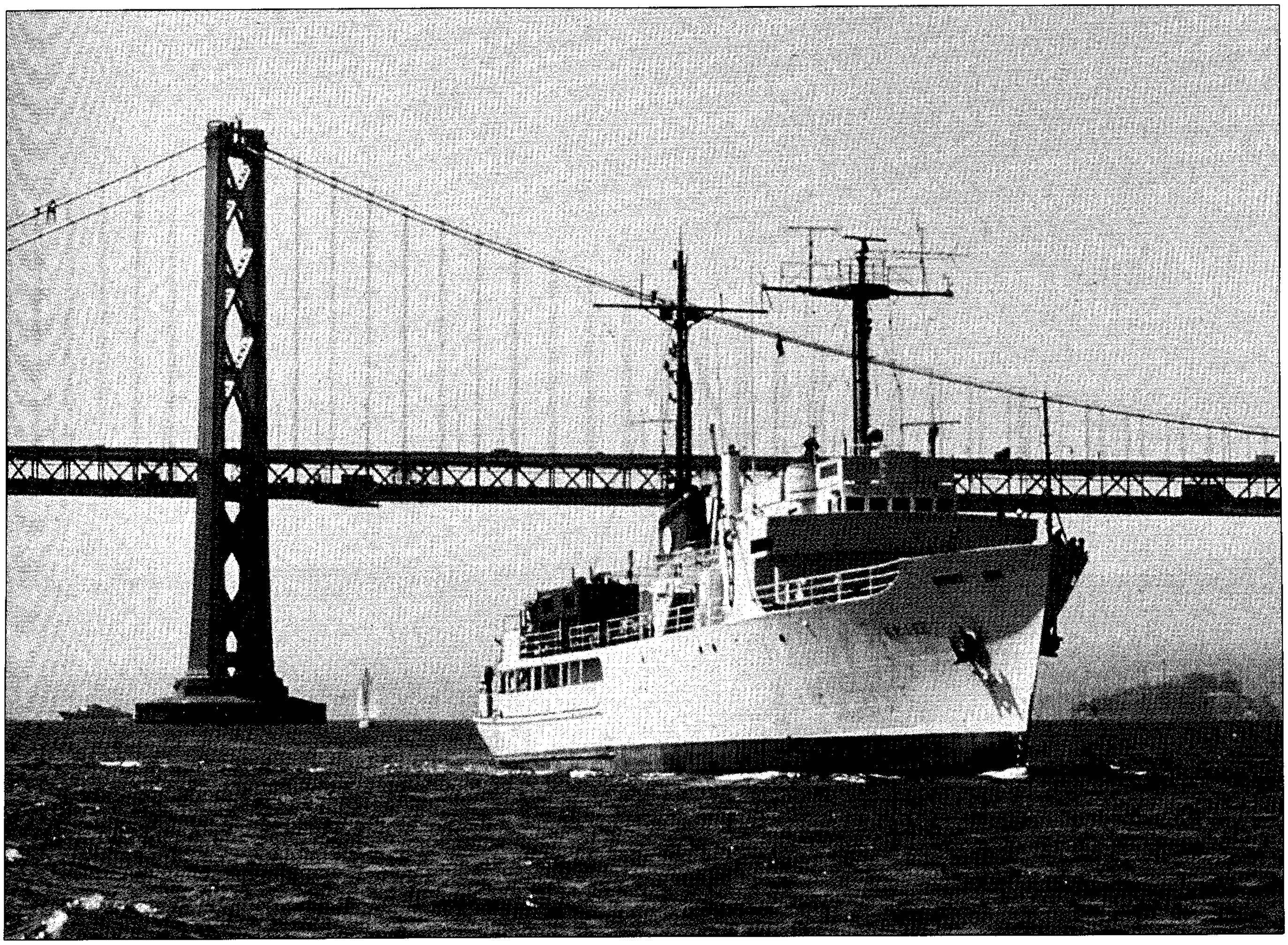

Published as a supplement to *Eos*, October 27, 1992

EOS, TRANSACTIONS, AMERICAN GEOPHYSICAL UNION 1992 FALL MEETING VOL. 73, NO. 43, OCTOBER 27, 1992 / SUPPLEMENT