

SESSION 120, Tectonics IV: Himalayan Tectonics

4:00 PM Hauck, Michael L.

RAMPING OF THE MAIN HIMALAYAN THRUST & DEVELOPMENT OF THE SOUTH TIBETAN DETACHMENT & KANGMAR BASEMENT DOME: INDEPTH REFLECTION PROFILES IN SOUTHERN TIBET

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The Main Himalayan Thrust (MHT) is the active decollement for Himalayan thrust structures and is tied by field mapping and seismicity to a north-dipping reflector at ~25-45 km depth on INDEPTH deep seismic reflection profiles near 90°E lon south of the Indus-Tsangpo Suture Zone (ITSZ). The South Tibetan Detachment (STD), tied by surface outcrop to bright reflections, is a system of north-dipping low-angle normal faults between Indian basement and Tethyan cover rocks that has moved in tandem with foreland thrust structures (~24-17 Ma). The Kangmar Dome (KD), imaged as convex upward reflections throughout the upper crust, is a structural dome within the Tethyan Himalaya that exposes in its core a top to the north shear zone and Indian basement.

INDEPTH profiles in Dogen and Neiru (a.k.a. Gabo) Valleys demonstrate that the initially north-dipping STD is folded and resurfaces within the KD. Beneath the KD, the entire upper 30 km of crust is domed upward over an apparent termination of the MHT reflector marked by strong diffractions. We infer a major ramp on the MHT (~50 km S. of the ITSZ) which may root near the base of the 80 km thick crust, and propose that hanging wall uplift over the MHT ramp since ~20 Ma has caused the KD. Since basement domes are a common feature of the Himalaya, they may mark the current location of a major thrust ramp elsewhere along the orogen.

4:15 PM Cogan, M. J.

INDEPTH SEISMIC REFLECTION/REFRACTION EVIDENCE FOR MODERATE TO LOW-ANGLE DETACHMENT FORMATION OF SOUTHERN TIBET RIFT VALLEYS

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The southern Tibet Plateau is cut by a series of N-S trending Plio-Pleistocene rift valleys. An analysis of INDEPTH reflection/refraction data collected along the Yadong-Gulu rift, the largest of these rift systems, provides the first subsurface information from one of these rifts. E-W cross-sections have been analyzed in Dogen valley, Nieru valley (Gabo), and southern and central Yangbajain valleys. In each case, the valleys are floored by asymmetric Plio-Pleistocene sediment fills ranging from ~100 m to ~1.5 km deep. In general, the basement dips gently east ($\leq 5^\circ$). INDEPTH seismic reflection data from the central Yangbajain valley show a ~30° east-dipping reflector that projects up to the surface expression of the Nyainqentanglha Shear Zone.

Field geologic investigations along the INDEPTH survey route have shown the existence of previously unrecognized normal sense shear zones along the sides of Dogen and Nieru valleys. The shear zones are 200 to >500 m wide and are characterized by gently to moderately west-dipping mylonite with top-to-west shear sense. Metamorphic minerals in the footwalls of the shear zones indicate at least amphibolite grade metamorphism at the top of the detachment zones and increasing metamorphism down section. Steeply dipping range-front normal faults cutting Quaternary/Recent moraine and alluvial fan deposits may not cut the mylonites at depth.

The seismic reflection data coupled with the new geologic information, and geomorphic data from LANDSAT imagery suggests that the structure of the Yadong-Gulu rift is comparable to other well documented rift systems in which steep range-front normal faults terminate at, or sole into moderately dipping normal-sense detachments at depth. This, in turn, suggests that the N-S rifts in Tibet may have accommodated substantially more extension than has generally been presumed.

4:30 PM Ross, A.

REFLECTION BRIGHT SPOTS BENEATH SOUTHERN TIBET - IMAGES OF MAGMA BODIES?

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The most prominent feature of seismic reflection data acquired in Phase II of Project INDEPTH in southern Tibet is a series of high-amplitude reflections from about 15-20 km depth beneath the Yadong-Gulu rift system. These unusual events, here designated the Yangbajain Bright Spots, are part of a more extensive, though discontinuous, subhorizontal band of reflectivity defined by both multichannel CMP and wide-angle (inline and broadside) reflection recording. The CMP bright spots, however, all lie beneath the Yangbajain-Domxung graben of the Lhasa block. The use of explosive sources allows

reliable determination of reflection polarity; the bright spots are found to correspond to negative reflection coefficients. Although there are several possible explanations for high amplitude, reverse polarity reflections, the most convincing is that these bright spots correspond to magma intruded into the upper Tibetan crust. Strikingly similar bright spots have been reported from deep reflection profiles in other areas of Quaternary extension and/or volcanism, most significant perhaps being the Socorro Bright Spot imaged by COCORP profiling in the Rio Grande rift. The magma interpretation of this latter analogue was greatly bolstered by the identification of unusually strong shear wave reflections from microearthquake sources (e.g. A. Sanford and colleagues), local seismicity patterns, regional heat flow, contemporary uplift (magma inflation?), and-obviously- tectonic setting. A magma interpretation for the Yangbajain Bright Spots is certainly compatible with the widespread geothermal activity which occurs today across the southern Tibetan Plateau: one of the YBS even underlies the producing Yangbajain geothermal field. Heat flow values from the Yangbajain graben are comparable to values obtained for the Rio Grande Rift. The YBS also lie at the same depth as low resistivity and low velocity zones inferred from magneto-telluric and seismic refraction/receiver function measurements in the area. We suggest that the Yangbajain Bright Spots result from *in situ* melting triggered by post-collisional extension on the Tibet Plateau.

4:45 PM Harrison, T. M.

A MIDDLE MIOCENE THERMAL DISTURBANCE ASSOCIATED WITH DEVELOPMENT OF THE RENBU-ZEDONG THRUST, SOUTHEASTERN TIBET.

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Key to understanding the mechanisms of crustal thickening in the Himalaya and southern Tibet is knowledge of the sequence of thrusting. The relatively late discovery of the S-directed Gangdese thrust (GT) is owed to the fact that the younger, N-directed Renbu-Zedong thrust (RZT), the dominant structural feature along the suture zone in southern Tibet, generally obscures its exposure outside the ~100 km long Zedong window. The pattern of thermochronometry in the GT hanging wall and across the Late Cretaceous-Early Tertiary Gangdese batholith is consistent with significant motion on the GT occurring between 27-24 Ma. Thermochronological results on granitoid samples obtained from vertical traverses immediately above the GT reveal clear evidence of rapid cooling beginning at 27 Ma, but this picture becomes complex near the eastern end of the window where the RZT once again defines the suture zone. Thermochronological evidence from that region indicates that the Gangdese batholith was reheated during the middle Miocene, likely due to burial by the hanging wall of the RZT. Confirmation of this result is obtained from investigations of a NW-SE transect ~120 km east of the Zedong window near Lang Xian. Thrusting there along the RZT, which dips ~40°S, has exposed epidote-amphibolite facies Tethyan metasediments at record peak recrystallization temperatures of >450°C. These temperatures are significantly higher than those inferred from greenschist grade shelf sequence rocks further to the west, and suggest greater displacement on the RZT towards the eastern syntaxis. Near Lang Xian, the Tethyan metasediments are thrust northwards on the RZT directly atop granitoids of the Gangdese batholith. $^{40}\text{Ar}/^{39}\text{Ar}$ age spectra of K-feldspars from footwall granitoids reveal evidence of a profound thermal disturbance immediately beneath the RZT, the effect of which systematically decreases with increasing distance away from the RZT. Inverse modeling of the $^{40}\text{Ar}/^{39}\text{Ar}$ results using a variational approach constrains the timing of peak reheating to be between 18 and 11 Ma, suggesting that thrusting was active during this interval. Peak temperatures in the footwall vary from >350°C immediately below the RZT to ~260°C 15 km north of the fault trace where the effect of reheating appears to be minimal. The emerging pattern of thrust activity in the Himalaya and southern Tibet (i.e., GT, >27-24 Ma; MCT, ~24-18 Ma; RZT, ~18-11 Ma; MBT, <11 Ma) is one of general propagation towards the foreland interrupted by two out-of-sequence episodes; the middle Miocene RZT backthrust and a Pliocene reactivation within the MCT zone.

5:00 PM Edwards, M. A.

INFLUENCE OF THE KHULA KANGRI PLUTON ON THE EVOLUTION OF THE SOUTHERN TIBET DETACHMENT SYSTEM (STDS). NEW DATA FROM GONTO LA

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The STDS is a system of north-dipping, low-angle detachments which typically outcrop on the north flank of the high Himalaya and juxtapose Tethyan sediments of the hanging wall above a crystalline basement footwall. Burchfiel et al. (1992) did not recognise the STDS on a traverse east of the Khula Kangri massif (underlain by the leucogranite pluton) between Lhozag and La Kang. Here, the only major structure found, the Dzong Chu Fault (DCF), is restricted to the Tethyan sequences. We present observations of the STDS from a traverse along Gonto La; a <2km deep valley through the High Himalaya west of Khula Kangri. The field relationships here are interpreted to show how the evolution of the STDS was influenced by the Khula Kangri pluton and provide a simple hypothesis to explain the elusive nature of the STDS at Lhozag, to the east.

Leucogranite of the pluton makes up the lower portions of the valley walls in the central and northern parts of the valley and approximates a dome. Tethyan slates are juxtaposed above the leucogranite on the north side by a detachment fault dipping ~10°N. Mylonitic schist, including an injection complex, forms a >700m thick unit in the south, lying structurally above the leucogranite. The foliation of this schist is generally S-dipping, curved, and is parallel with the southern contact of the leucogranite. Locally, it truncates the mylonitic foliation at a low angle. The extensive mylonite has sense of shear structures suggesting top to north, and is interpreted to be the originally north-dipping shear zone of the STDS that was active during ductile extension. The domal nature of the leucogranite, the parallel nature of its contact with the mylonitic schist, and local cross-cutting of the mylonitic foliation by undeformed leucogranite suggests (1) that the mylonitic schist existed before the

4:30 PM Lehmann, Christoph

DEPOSITIONAL FACIES, SEQUENCE STRATIGRAPHY AND DROWNING OF THE COAHUILA CARBONATE RAMP (ALBIAN), NORTHEASTERN MEXICO
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The Lower Cretaceous (Albian) Coahuila carbonate platform of northeastern Mexico is coeval with the economically significant Valles and Golden Lane (Tuxpan) platforms to the south and the Glen Rose-Edwards-Stuart City platform to the north in Texas. Approximately 16,000 m of the Acatita/Aurora/Upper Tamaulipas Formations have been logged on a decimeter-scale over an area of 100,000 km² to determine platform geometry and facies relationships, and to develop a sequence stratigraphic framework for the Coahuila carbonate platform.

The Coahuila carbonate platform is a distally steepened ramp attached to the Coahuila basement block. Three distinct facies assemblages characterize the three major paleogeographic elements of the Coahuila ramp. 1) The ramp interior (Acatita Formation) is composed of more than 60 evaporitic parasequences deposited in a hypersaline lagoonal environment. The evaporitic parasequences are composed of a basal evaporitic lithofacies shallowing upward to a high-energy, skeletal, peloidal packstone/grainstone. 2) The ramp margin (Aurora Formation) is composed of a massive ooid-peloid grainstone that exhibits progradational geometries, representing a high-energy barrier shoal. Up to 140 peritidal parasequences overlie the massive grainstone, reflecting protected tidal-zone environments in the lee of the barrier shoal. Meter-scale parasequences are composed of a basal, skeletal, peloidal grainstone containing rudists, fining and shallowing-upward into a dolomitized fenestral mudstone or tidal-flat laminite. 3) The deep ramp (Upper Tamaulipas Formation) is composed of muddy hemipelagic lithofacies and can be subdivided into a proximal hemipelagic subfacies and a distal hemipelagic subfacies separated by a locally-developed steepened slope.

Both the evaporitic and peritidal parasequences are interpreted to represent high-frequency accommodation events (10⁴-10⁵ year range). These parasequences are arranged in several parasequence sets and form a pattern of long-term decrease in accommodation space, culminating in a major sequence boundary (mid-Albian), followed by an increase in accommodation space. The Coahuila carbonate platform was abruptly drowned, marked by the deposition of a 20 m thick, planktonic foram-dominated, silty, laminated mudstone. This drowning event terminated Cretaceous platform development in the region and might coincide with the late Albian globally recognizable Oceanic Anoxic Event (OAE 1C).

4:45 PM Prothero, D. R.

MAGNETIC STRATIGRAPHY OF THE LATE MIDDLE EOCENE COLDWATER FORMATION, CENTRAL VENTURA COUNTY, CALIFORNIA: IMPLICATIONS FOR SEQUENCE STRATIGRAPHY

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Until recently, the middle Eocene Coldwater Sandstone could not be precisely dated beyond its "Tejon Stage" molluscs (which range from 33-44 Ma). Yet the upper Coldwater redbeds (which grade into the the overlying middle Eocene Sespe Formation in upper Sespe Creek, Ventura County, California) produces several mammalian faunas which greatly improve the biostratigraphic control. After removal of magnetic overprinting by stepwise thermal demagnetization, most samples yielded a stable primary remanence that passed a reversal and fold test, and shows a clockwise rotation of about 100° ± 17° (consistent with other pre-Miocene units in the western Transverse Ranges). Magnetic stratigraphy and refined chronostratigraphy of the late Uintan and Duchesnean mammals found within the redbeds in the Coldwater show that the upper Cozy Dell-Coldwater-Sespe sequence in central Ventura County spans Chrons C19r-C18n (approximately 39.5-42.5 Ma). The late Uintan Hartman Ranch l.f. occurs near the top of Chron C19n (about 41.2 Ma), in good agreement with the magnetostratigraphic position of the similar Tapo Canyon and Brea Canyon local faunas in Simi Valley. Several Duchesnean localities (with *Duchesneodus* and *Amynodontopsis*) are known in this area; these all occur in early Chron C18n (about 40 Ma).

These new biostratigraphic and magnetostratigraphic data allow a test of two recent sequence-stratigraphic models proposed for the Cozy Dell-Coldwater-Sespe Formations. Campion et al. (1994) interpreted three sequence boundaries in this interval, which they correlated with the Ta3.6-Ta4.4 parts of the Haq et al. (1987) curve. With better chronostratigraphy, it is clear that none of these three sequence boundaries are eustatically controlled, and they are miscorrelated by 4-5 million years (they actually occur within Ta3.4 or Ta3.5). Clark (1994) recognized three different sequence boundaries in the same sections, but did not suggest eustatic control; indeed, none of his sequence boundaries match the Haq et al. (1987) curve, either. Such mismatches further reinforce the caveat that sequence-stratigraphic correlations are only as good as the biostratigraphic data on which they are based.

5:00 PM Pinous, O. V.

Upper Eocene - Lower Miocene Facies, Sequences, and Sea-Level Change Interpretation from the Strata of the Northern Aral Sea Region (Kazakhstan),

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The Northern Aral region was in the northeastern part of Upper Eocene - Early Miocene Tethys, and was a transitional zone between continental and marine depositional environments on a passive margin. Clastic and carbonate deposition occurred in a range of facies from fluvial and lacustrine in coastal plains (Turgai Trough) to deep marine with condensed sections and turbidites (Usturt Plateau). The section is characterized by explicit cyclicity which is interpreted to be caused by tectonic subsidence, sediment supply rate, and eustasy. Paralic facies (deltaic, lagoonal, estuarine), that comprise the transition zone from continental to marine sedimentation are especially sensitive to the relative sea-level change. The excellent exposure of these strata in numerous outcrops and the presence of a number of wells drilled throughout the area makes it

possible to examine in detail different facies successions and trace their lateral and vertical transitions within the stratigraphic units. Preliminary stratigraphic and sedimentologic analyses of outcrops and wells made it possible to subdivide the section into depositional sequences and reconstruct the development of the depositional systems and their response to sea level change. Despite significant spatial in tectonic subsidence and sediment supply rates, sequences and systems tracts can easily be traced throughout the margin. Preliminary results suggest that the margin developed in a tectonic and sedimentary regime generally similar to the U.S. Atlantic and Gulf margins, and that eustasy played a major role in controlling sedimentation. However, in some biostratigraphically poorly correlated intervals, sea-level events reflected in the Aral sections do not correspond to those reported from Atlantic and Gulf Coast margins. For example, the most significant sea level fall in the Aral region appears at the Eocene/Oligocene boundary or in Lowermost Oligocene (according to present biostratigraphic data), but in the U.S., a similar sea level fall is inferred in the Middle Oligocene. While it is possible that the interplay between subsidence and sedimentation conspired to cause the basal Oligocene event in the Aral region and the Middle Oligocene event in the Atlantic and Gulf margins independently, we consider it more likely that they were caused by the same eustatic event, and that the biostratigraphic correlation of the Aral strata bear re-examination. Subsequent detailed stratigraphic analysis of the Aral sections may provide important data for identification of true Eocene-Miocene eustatic events.

5:15 PM Guertin, Laura A.

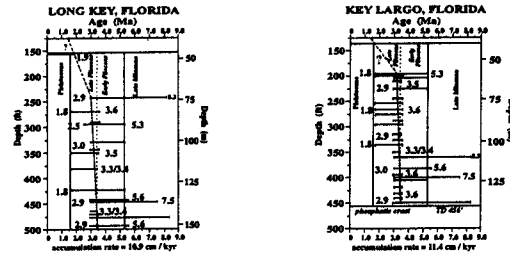
HIGHSTAND(?) MOBILIZATION AND EMPLACEMENT OF NEOGENE SILICICLASTIC SEDIMENTS, SOUTHEAST FLORIDA

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Two new continuous core borings show a surprisingly thick (~100 m) package of siliciclastic sediments in the shallow subsurface of the Florida Keys. The siliciclastic sediments are underlain by middle Miocene(?) limestone and overlain by latest Pliocene(?) and Pleistocene limestone, serving as the foundation for the modern Florida reef tract. Initial results from biostratigraphic (planktic foraminiferal) data indicate that marine deposition of these siliciclastic sediments on the southeast Florida peninsula occurred during the middle Pliocene (~3.6-2.9 Ma).

Age/depth plots have been generated from constraining biohorizons of first and last appearances of key species found in the siliciclastic section of both cores (see figures). The plots suggest that emplacement of the siliciclastics in southeast Florida was at a relatively high sedimentation rate (10.9-11.4 cm/kyr), within a ~0.5 m.y. interval. The middle Pliocene age for the siliciclastics is also coincident with a proposed highstand in sea level (mid-Pliocene warm period) and the initial lowering of sea level associated with the onset of Northern Hemisphere glaciation (~3.2 Ma). If confirmed, these results suggest that the mobilization and redistribution of both the fine- and coarse-grained siliciclastic sediments of southeast Florida occurred during a highstand and/or during the subsequent, initial fall in sea level.



SESSION 120, 1:30 PM

Wednesday, November 08, 1995

Tectonics IV: Himalayan Tectonics

ENM 39

1:30 PM Pivnik, David A.

TECTONICS AND SEDIMENTATION IN THE PAKISTAN FORELAND DURING THE PLIO-PLEISTOCENE

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Pliocene and Pleistocene syntectonic sedimentation in Pakistan occurred in response to tectonically and geographically varied deformational events related to the most recent stages of Himalayan convergence. The availability of accurate magnetostratigraphic, fission-track, and biostratigraphic ages of the upper Siwalik Group allows for the correlation of synchronous yet structurally disparate deformation that occurred throughout the Himalayan orogen. Superimposed on the backdrop of deposition of the main foreland fluvial system, the Indus River, were numerous basins which received sediment in response to coeval, local tectonism which partitioned the foreland. In the hinterland region, intermontane basins such as the Skardu Basin rapidly aggraded from ~3.0 to 0.75 Ma in response to sediment ponding behind the uplifting Nanga Parbat Massif. The Karewa sequence in the Kashmir intermontane basin records uplift of the Pir Panjal Range from ~4.0 to 1.5 Ma. In the Campbellpore and Peshawar intermontane basins, deposition

WED pm

ABSTRACTS WITH PROGRAMS

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