can penetrate effectively into the lower mantle. We also conducted a kinetics study of garnet-postgarnet transformation (Kubo et al., Nature, 2002), and found that the transformation rate is sluggish resulting in metasltable garnet in the dry and cold oceanic crust. On the other hand, our experiments on the in situ X-ray diffraction in MORB indicated that water enhances the reaction kinetics significantly. Therefore, the garnet-postgarnet transformation completes in the wet and cold subducted slabs. Recently, the seismic reflectors have been reported in the upper part of the lower mantle (e.g., Kaneshima and Helfflich, 1998; Niu et al., 2002). The seismic reflectors might be explained by the subducted oceanic crust in the lower mantle. Niu et al. (2002) reported that the seismic reflectors have characteristic properties, i.e., an increase in the density, nearly constant Vp, and a decrease of Vs in the reflectors. Recent mineral physics data on high pressure minerals in the oceanic crust including NAL phase and CF phase (Ono, 2002; Vanpeteghem et al, 2003) may provide information on the state of the oceanic crust in the lower mantle. Our preliminary analysis suggests that the change in physical properties of the seismic reflectors can not be accounted for by a simple chemical change from the lower mantle peridotite to the oceanic crust of the perovskite lithology with or without metastable garnet. Additional mechanisms are needed to explain a decrease of Vs in reflectors suggesting anelastic effects such as a possible existence of fluid or melt.

T21A-06 0915h INVITED

A watered-down primordial lower mantle

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For more than a decade, conflicting evidence between seismic tomography and isotope geochemistry of rare gases has thwarted the construction of a unifying convection model and blurred our vision of lower mantle chemistry and mineralogy. All body wave models vividly depict lithospheric plates penetrating the 660 km discontinuity such as the Farallon and the Tethyan plates. In contrast, the presence of helium with a high $^{3}He/^{4}He$ ratio and, even more, of solar neon in OIB attests to the presence of undegassed material at depth. Current models of tracer redistribution by convection do not resolve this conflict and are limited to the description a whole range of regimes with variable extent of layering. We addressed this problem through the residence time distribution theory, which shows that the time different parcels of mantle survive extraction and degassing from a well-stirred mantle is exponentially distributed. Whole mantle mixing only destroys the primitive signature of the average lower mantle (at the scale of the global reservoir) but leaves some small parcels untouched since terrestrial accretion. From available isotopic data, we assess that the lower part of a unhindered convective mantle may contain several percent primordial material. If the 660 km discontinuity is a partial hindrance to vertical mixing, this proportion is significantly higher. The most likely texture of the lower mantle is an intricate layering of material recycled from the surface and primordial material while its chemical composition is geochemically enriched with respect to the upper mantle. This simple concept accounts for the coexistence of the primordial character of rare gases, the recycled character of lithophile-element isotope compositions in OIB, the apparent lack of ^{142}Nd anomalies, and the missing component inferred from a number of geochemical systems. The marble cake incorporates different ingredients at different depths: mostly residual mantle and recycled oceanic crust at the top and more oceanic plateaus and primordial material at the bottom.

T21A-07 0930h

High-Pressure Brillouin Measurements on Single-Crystal Ferropericlase, (Mg0.94Fe0.06)O: Implications for Earth's Lower Mantle

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The determination of accurate compositional models of Earth's interior from observed seismological data requires knowledge of the elastic properties of candidate phases under conditions approaching those of Earth's interior. Ferropericlase, (Mg,Fe)O, is expected to coexist with silicate perovskite in Earth's lower mantle (660 C 2900 km depth), and will therefore have a major influence on all properties in this region of the Earth. However, the effect of iron on the single-crystal elasticity of MgO at high-pressures is still poorly constrained. In this contribution, we present the single-crystal elastic properties of ferropericlase, $(Mg_{0.94}Fe_{0.06})O$ [hereafter referred to as Fe6], measured by Brillouin scattering on a sample compressed to 13.3(4) GPa with a diamond anvil cell. Within the uncertainties, we find that at room-pressure the bulk modulus of Fe6 is unchanged from MgO, but that the shear modulus of Fe6 is about 7% less than that of MgO. Furthermore, the elastic anisotropy of Fe6 is about 10% greater than that of MgO at room-pressure, in excellent agreement with results obtained using gigahertz ultrasonic interferometry on the same sample [1]. Our measurements also allow us to assess the effect of iron on the pressure derivatives of the sound velocities and elastic moduli of MgO. Results indicate that 6 mol% Fe in MgO does not significantly affect the pressure derivatives of the aggregate elastic properties of ferropericlase compared to MgO. At the highest pressure obtained in this experiment, the elastic anisotropy of Fe6 is close to that of MgO. In light of these new high-pressure measurements on Fe6 and other recent measurements on Al-bearing $MgSiO_3$ perovskite [2], implications for the mineralogy of Earth's lower mantle will be discussed. *References:* [1] S.D. Jacobsen *et al.* (2002) J. Geophys. Res., 107, 2001JB000490 [2] J.M. Jackson *et al.* (2003) Geophys. Res. Abstr., 5, EGS-AGU-EUG Joint Assembly, France, EAE03-A-12122.

T21A-08 0945h

Compositional Effects of Trace Element Partitioning Between Mg-Silicate Perovskite and Silicate Melt

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Models for the accretion of the Earth propose the existence of a deep magma ocean that may have extended to depths corresponding to the present day lower mantle. Crystallization and fractionation of such a deep magma ocean could lead to chemical differentiation and stratification within the Earth. While it seems that the upper part of Earth's mantle has been rehomogenized by subsequent mantle convection it is possible that chemical layering may have survived in the lower mantle causing a chemical and geophysical signature. In this study we present new experimental data on trace element partitioning between Mg-silicate perovskite (Mg-pv) with various compositions and coexisting silicate melt. High pressure melting experiments have been performed in Re and graphite containers in a multi-anvil apparatus between 25-27 GPa and temperatures up to 2573 K. Starting materials were synthetic pyrolite compositions with varying aluminum contents and a CI chondrite model composition, both doped with a selection of trace elements at the 100-500 ppm concentration level. Trace elements in crystals and quenched melt were analyzed by secondary ion mass spectroscopy. Mg-pv is found to have an affinity for four-valent high field strength elements (Ti, Zr, Hf) with a tendency for higher mineral-melt partition coefficients ($D^{Mgpv/melt}$) with increasing Al content of the solid phase. Large ion lithophile elements (LILE) and rare earth elements (REE's) are found to be incompatible in Mg-pv except for Lu for which the $D^{Mgpv/melt}$ value also increases with increasing Al content. We consider possible effects on the crystal chemistry of Mg-silicate perovskite as a function of major element concentration and discuss the question to what extend perovskite fractionation into a hidden reservoir in the deep mantle could have occurred without disturbing chondritic element ratios preserved in the residual upper mantle

T21B MCC: 3005 Tuesday 0800h

Development of Fault Systems Through Time: Process and Rates I

Presiding: **J M Bull,** Southampton Oceanography Centre**; P Cowie,** Edinburgh University

T21B-01 0805h INVITED

Fault and Rift evolution - All Features Great and Small

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It has been recognised for some time that oceanic ridges propagate and that the process involves the transfer and concentration of stored elastic energy to the site where new rift is being created. Together with flexure associated with volcano loading and subduction, the evidence that oceanic lithosphere has long-term elastic strength seems convincing. Data demonstrating long-term strength and propagation-like behaviour for continental lithosphere has taken longer to collect. For the Gulf of Aden and two major faults (the Altyn Tagh and North Anatolian faults) the evidence now appears to be convincing. Over periods of many millions of years these fault have evolved in a way most simply explained if the continental lithosphere, like that of the oceans, is elastic overall. However, while the propagation of continental faulting or rifting is similar to that observed in engineering materials, there are important differences. A central tenant of traditional fracture mechanics is that big cracks grow at the expense of smaller ones, which therefore are unimportant. This is not true for the Earth, as demonstrated by the scale distribution of faults and earthquakes. Damage or breakdown zones also appear to be larger than those in engineering materials and to scale with the length of the associated fault. Finally, unmodified concepts of Critical Stress Intensity Factor cannot applied to the evolution of faulting in the Earth. Recent studies of long-term fault growth sheds new light on this problem. The cumulative slip profiles of such faults appear to be triangular and can only be explained by the development of large damage zones off the main fault, that incorporate macro- rather than micro-scale fissuring. Such triangular faults or cracks cannot behave like elliptical (or modified elliptical) ones since the stress intensity factor at their tips is zero. Hence, large faults are not favored with respect to small ones, and in the absence of interactions, all faults are equally likely to extend. Although these faults do extend, this consists of a process of linkage. The highly irregular slip profiles of long-term faults is consistent with this view.

T21B-02 0825h

Controls on Growth Rates of Normal Faults

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A recent model of fault growth suggests that many faults establish their lengths rapidly and for much of the duration of deformation grow principally by the accumulation of displacement. For faults consistent with this model we investigate the factors controlling displacement rates and average recurrence intervals using the lengths and displacement rates for 274 normal faults from 4 extensional regions. Our analysis of the evolution of fault systems on geological time scales (i.e. 60 kyr to 7 Myr) suggests a broad positive correlation

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between fault length and displacement rate for each region. Combining established earthquake-scaling laws with fault length and displacement rate data permits average recurrence intervals to be estimated. We conclude that earthquake recurrence intervals in a particular fault system are, to a first approximation, constant for a range of fault sizes. Therefore, larger faults generally have higher displacement rates than smaller faults because they accommodate larger earthquakes with greater coseismic slip. Stochastic and numerical modelling results suggest that fault interaction (and location) and intrabasinal strain rate variations are the principal factors responsible for scatter in the relations between length and displacement rate of individual fault systems; migration of the locus of faulting and death of large faults could be important in other areas. Further analysis indicates that decreases in recurrence intervals between fault systems arise principally due to increases in regional strain rates. A negative correlation between average recurrence interval and basinal strain rate is confirmed by independent estimates of recurrence intervals from paleoseismological studies, and supports the notion that the number of large active faults in a system remains approximately stable, with increased strain rates accommodated by greater fault displacement rates rather than by the introduction of more large active faults. Basin-wide strain rate and fault size are the primary controls on recurrence intervals, with fault interaction and intrabasinal strain rates being important secondary factors.

T21B-03 0840h

Fault Population Evolution in the Central Dip Province of the Suez Rift, Egypt

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Structural and stratigraphic analysis of outcrop and subsurface datasets from the late Oligocene-Recent of the Central Dip Province Suez rift, Egypt suggest that fault segment linkage, migration of the locus of fault activity, and displacement localisation were important processes controlling evolution of the normal fault population. Initial fault activity was distributed across fault blocks on fault segments that attained their final length within 1-2 My of rifting. These initial segments then either grew by increasing displacement and linked to form longer segmented fault zones or became inactive, during a rift initiation phase that lasted 6-8 My. Following this rift initiation phase, displacement became localised on >15-25 km long border fault zones bounding major, 10-20 km wide tilted fault blocks and many of the early high-displacement intra-block fault zones became inactive. Following displacement localisation onto the major hard-linked fault zones bounding the tilted fault blocks, the locus of fault activity and maximum displacement continued to migrate, with a trend to longer, but fewer active fault zones to the present day. This migration of fault activity between major crustal-scale normal faults can be viewed in terms of strain localisation at the rift scale.

T21B-04 0855h

Effects of Driving Stress and Rheology on the Temporal and Spatial Distribution of Faulting Within Intraplate Seismic Zones

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Within stable continental regions, present-day seismicity is often highly localized. The reasons are not well understood, but intraplate seismic zones frequently overly ancient failed rift zones. Such zones may be weak relative to their surroundings, thereby explaining the repeated concentration of deformation at these locations over hundreds of millions of years. One example, the New Madrid Seismic Zone in the south-central U.S. produced 3 M 7.5 events in 1811-1812. Within intraplate weak zones, fault geometry, the temporal evolution of earthquake repeat times, and the transient vs. steady-state production of large earthquakes depends on the source of stress that drives seismicity and the zone's rheological characteristics. If the weak zone is loaded via far-field plate driving forces, stresses concentrate at the weak zone boundary. As a result, major rift bounding faults may be reactivated. The concentration of far-field stress will also be continuous over periods of a few million years and major earthquakes will be continuously produced. Alternatively, the stress driving seismicity could derive from weak zone relaxation following local or regional perturbations to the stress field (e.g. fluid effects, thermal effects, and/or gravitational loading due to buoyancy, topography, or other surface loads). Finite element models show that these transient perturbations yield geologically short-lived bursts of seismicity during which deformation rates and earthquake recurrence intervals change with time as stresses are redistributed and relaxed. The spatial distribution of faulting is dependent on 1) the geometry and lateral extent of the weak zone at depth and 2) the lateral distribution of strength in the overlying seismogenic crust. To investigate the latter effect, plastic rheologies are used which permit the formation of faults of arbitrary orientation. Relaxing weak zones increase stress in an area of the upper crust whose lateral extent is equal to that of the underlying weak zone. For a homogeneous elastic layer, strain-rates are highest above the center of the weak zone potentially activating faults at this location. Activation of weak faults at other locations during the initial stages of the relaxation process may significantly alter the spatial distribution of faulting.

T21B-05 0910h

Controls on the Growth and Maximum Size of Fault Arrays and Fault Segments–Insights from Experimental Clay Models

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We have used a series of scaled experimental models with clay to study the nucleation, growth and linkage of fault arrays and their constituent fault segments. We have varied the clay thickness and the magnitude, rate, width, and obliquity of deformation. We have also varied the basal boundary conditions: 1) focussed deformation associated with the edges of moving metal plates or metal blocks, simulating the effects of fault reactivation on a cover sequence, and 2) deformation above a rubber sheet, simulating distributed deformation. For small amounts of strain, the lengths of fault arrays and segments increase with increasing deformation and increase with decreasing deformation rate. Most fault arrays and segments ultimately achieve a maximum' length. This length depends on mechanical-layer thickness (increasing as thickness increases), deformation-zone width (increasing as width increases), and obliquity (decreasing as obliquity increases). Mechanical-layer thickness and deformation-zone width have an especially strong influence on the 'maximum' length of fault segments. The length of the fault array that develops during fault reactivation is strongly controlled by the length of the underlying reactivated fault, whereas the length of the constituent fault segments is controlled by the factors discussed above. Although a hard-linked fault array ultimately develops from these segments (given enough displacement on the reactivated fault), evidence of the location of former segment boundaries is long-lived. This evidence includes breached relay ramps, fault-displacement folds, and fault strands. The persistence of these features decreases with increasing displacement on the reactivated fault, decreasing thickness of the cover sequence, and decreasing obliquity. As most fault populations have a 'maximum' length, we expect that power-law size distributions will be uncommon. Our experimental models indicate that an exponential size distribution describes most fault populations. An exception is fault populations that form during orthogonal deformation at low strains. At higher strains, these fault populations also exhibit an exponential size distribution, with a power-law to exponential transition occurring at higher strains in thicker mechanical layers. As the maximum length of faults is limited in the experimental models, we expect that the scaling law between length and displacement will change with increasing strain. This may contribute to the large scatter in experimental and natural length-displacement data.

T21B-06 0925h

How Significant is Segment Linkage in Fault Growth?

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There are two contrasting models for the formation, and eventual linkage, of segmented normal fault arrays. Over the past 10 years, the preferred model attributes their formation to the interaction of initially isolated normal faults. An alternative view is that segmented fault arrays form as by-products of the localisation and 3-D propagation of individual faults within heterogeneous rock volumes. The distinction between these two models is crucial as acceptance of one model over the other has a profound impact on our perception of fault growth and linkage. We suggest that, in most cases, attributing fault growth to the incidental overlap and linkage of previously isolated faults arises from a 2-D view of fault geometry, with the implicit assumption that fault growth approximates a 2-D process. This perspective places great significance on the 2-D linkage process, with hard-linkage providing the prime means of fault growth, without acknowledging the potential kinematic equivalence of hard- and soft-linkage (e.g. such as relay zones and associated relay ramps). The alternative view, that segments arise from the 3-D segmentation and bifurcation associated with the propagation of individual faults, acknowledges that on arbitrary inspection planes soft-linked segmented arrays may link into a single surface in 3-D or may evolve into a hard-linked array with increasing displacement. This model predicts instantaneous interaction, and kinematic coherence, of fault segments and attaches less significance to the progressive change from soft- to hard-linkage; segment linkage is a local response to high strains at segment boundaries (i.e. relay zones). Using examples of segmented fault arrays from outcrop, analogue and seismic datasets, we show that they arise from the propagation of individual faults and that the scale of segmentation can sometimes be related to the nature of the faulted sequence. These arrays form kinematically coherent systems that are equivalent to single faults, both in terms of aggregate displacement profiles and deformation of the surrounding rock volume. With continued fault growth subsequent hard-linkage is inevitable and whilst this linkage may have a profound effect on the appearance of a fault map, the impact of faults on fluid flow or the scatter on indiscriminate fault scaling plots, its impact on fault growth, such as displacement and mortality rates on geological time scales, may be rather limited.

T21B-07 0940h

Deformation near the ends of Normal Fault Scarps

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Surface deformation along scarps of active normal faults on Kilauea volcano, Hawaii, reflects how the faults grow. We have mapped deformation near the east end of one east-striking fault that dips to the north, and the pattern resembles that along the east end of a previously-mapped fault that dips to the south. The scarps are breached monoclines with gentle monoclinal flexure extending past the end of the fault scarp trace. The monoclines demonstrate that the faults are growing from depth up towards the surface rather than from the surface down. Fractures on the monoclines form an echelon pattern. Monocline fractures strike east-southeast near the end of the fault that dips south; they strike east-northeast near the end of the fault that dips north. Belts of fissures characteristically form on both the uplifted footwall and the hanging wall, with a belt of buckles forming between the fault scarp and the hangingwall fissures. Fissures on the footwall have apertures about three times larger than those on the hangingwall. The belts of fissures and buckles are roughly parallel to the fault scarp away from the fault scarp ends, but these belts converge towards the end of the scarp trace. Away from the scarp end, fissures on the footwall generally strike roughly subparallel to the fault. Near the scarp trace end, the fissures form a pronounced echelon pattern. They strike east-southeast near the end of the fault that dips south, and they strike east-northeast near the end of the fault that dips north. The footwall fissures thus mirror the pattern of the fractures on the monocline. The pattern of fractures and fissures vary systematically with position rel-

ative to the fault tip. Three-dimensional boundary element analyses show that the fracture and fissure patterns are consistent with the along strike propagation of a normal fault as it grows towards the surface.

T21C MCC: Level 1 Tuesday 0830h

Taking the Measure of Deforming Landscapes I Posters *(joint with G, H)*

Presiding: **M A Ellis,** Center for Earthquake Research and Information, University of Memphis**; A L Densmore,** Institute of Geology, ETH Zürich

T21C-0461 0830h POSTER

Convergence history, topography, and early structural evolution of an obliquely convergent oceanic plate boundary: central and southern Macquarie Ridge Complex, Southwest Pacific

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Deformation along the Australian-Pacific transpressional plate boundary south of New Zealand (Macquarie Ridge Complex - MRC) since 5.9 Ma (anomaly 3Ay) has been accommodated by vertically displaced crust and variable amounts of strike slip faulting and/or underthrusting. Variable convergent histories result from the interplay of the close proximity of a drifting pole of rotation and the curvilinear trace of the plate boundary fault. We apply geomorphologic techniques to swath bathymetry data to quantify the amount of interplate deformation along three, distinctly oriented, 300-350-km long segments of the plate boundary since 5.9 Ma. Between 51°S and 61°S we calculate volumes of crust within 70 km of the plate boundary that are vertically displaced from the average seafloor depth occurring beyond the zone of active deformation. These volumes are compared to: (1) variable convergence angles, (2) the cumulative amount of perpendicular convergence predicted by stage pole rotations, and (3) active faulting at the seafloor in order to characterize the geodynamic evolution of the three different regions. Displaced volumes (anomalously shallow and deep bathymetry) adjacent to the plate boundary are proportional to the cumulative amount of plate boundary-normal convergence since 5.9 Ma. We integrate our results with four gravity transects across the central and southern MRC, illustrating the lithospheric-scale morphologic and structural evolution as underthrusting initiates at this obliquely convergent oceanic plate boundary. Along-strike morphologic changes in the MRC can be attributed primarily to the variable angles of convergence since 5.9 Ma. A convergence angle of $\sim 25°$ marks the transition from strike-slip dominated faulting and large displaced crustal volumes to partitioned underthrusting and strike-slip faulting, and relatively low displaced volumes. Regions where convergence angles have not exceeded 25° correspond to significant bathymetric troughs, representing failed attempts to develop thrust faults. Active thrust faults and deeper bathymetric trenches occur where convergence has been $>25°$ since 5.9 Ma. Thus the MRC can be used to help constrain some of the convergence characteristics necessary for establishing underthrusting at obliquely convergent oceanic lithosphere settings.

T21C-0462 0830h POSTER

Rates of Fault Growth and Landscape Development in Central Otago, New Zealand

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Central Otago is a region dominated by NE trending anticlinal ridges which form above buried reverse faults. Slow average velocities (3-5 mm yr^{-1} from GPS), coupled with low erosion rates due to the aridity of the region make this an ideal area to study landscape forming processes over unusually long time periods. DEM and drainage pattern analysis of the Rough Ridge system shows that South Rough Ridge has propagated northwards, pushing the Oliverburn stream to the north as it does so. This stream has cut strath terraces, which record the history of the progressive movement of the stream. After abandonment, these terraces are uplifted and warped by the continuing growth of the ridge. Quartzite boulders on the terrace surfaces were analysed for cosmogenic ^{10}Be and ^{26}Al in order to gain an approximate age for the abandonment of each terrace. Whilst the exact time at which a river cuts down and begins to create a new strath terrace may depend on many variables, such as a change in climatic regime, the relative timing of abandonment of all of the terraces must be a proxy for the growth of the ridge, as it is controlled by the movement of the stream northwards. The progressive warping of higher terrace surfaces and the lack of terrace surfaces of a similar height in the basin to the east of the range indicates that local, rather than regional, base level changes are the controlling factor of terrace formation. The qualitative interpretation of the geomorphology of this region is confirmed by the cosmogenic results. On the tip of South Rough Ridge we obtain an average uplift rate of 0.10-0.15 mm yr^{-1} and a lateral propagation rate of 1.0-2.0 mm yr^{-1} averaged over the last 450,000 years. On neighbouring Rough Ridge, we also obtain minimum ^{10}Be ages of 1 Myr, indicating extremely low erosion rates in this area.

T21C-0463 0830h POSTER

Topographic Development and Exhumation of the Santa Cruz Mountains, From Fission Track Data and Deformation and Erosional Modeling

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Tectonic uplift within and advection of material around restraining bends along strike-slip faults is a controlling factor on the topography in these tectonic environments. We investigate the deformation, exhumation, exposed rock types, and topography within the Santa Cruz Mountains (SCM) along the San Andreas Fault to understand how topography develops in this region due to the presence of an 8^o restraining bend. Thermochronologic studies indicate that rock uplift is concentrated within an ∼30–40 km long zone to the northeast of the restraining bend. Specifically, reset Apatite Fission Track (AFT) samples in the Sierra Azul portion of the SCM indicate that at least three kilometers of exhumation has taken place in the last 3 Ma, while un-reset AFT samples southwest of the fault indicate that exhumation has been limited. We modeled the total amount of rock uplift through time experienced by crust moving through this restraining bend using the Poly3D boundary element model. We found that even when rock uplift was maximized by fixing the restraining bend to the northeast plate, it was insufficient to reset AFT samples within the Sierra Azul block. Therefore, active contractional structures that strike parallel to the SAF are apparently required to localize uplift in this area and bring rocks from greater than 3 km to the surface. We used Digital Elevation Model and Digital Line Graph analyses of the topography to constrain the amount and distribution of basin relief in areas that have undergone large and small amounts of exhumation along the northeast and southwest sides of the fault, respectively. High basin relief and averaged hillslope angles were correlated most strongly with different geologic units, and to a lesser degree, locusts of uplift defined by the AFT data. Therefore, basin relief appears undiagnostic of high uplift rates within this area without accounting for variations in erosional resistance between lithologic units. To understand the relative role of rock erodibility and uplift in the construction of relief in this area, we have coupled a three-dimensional erosional model that considers bedrock incision to the deformation predicted by the mechanical boundary element model. We are using this model to calibrate the erosional parameters required to produce the topography observed in this area. We will then use this model in a forward sense to assess the conditions under which rock erodibilities and/or rock uplift rates dominate the topographic signature in these types of environments.

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Lateral propagation of folding and thrust faulting at Mahan, S.E. Iran

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Folding identified near the town of Mahan in S.E. Iran has no record of historical activity, and yet there are clear geomorphological indications of recent fold growth, presumably driven by movements on underlying thrust faults. The structures at Mahan may still be capable of producing destructive earthquakes, posing a considerable hazard to local population centres. We describe a drainage evolution that shows the effect of lateral propagation of surface folding and the effect of tilting above an underlying thrust fault. River systems cross and incise through the fold segments. Each of these rivers show a distinct deflection parallel to the fold axis. This deflection starts several kilometres into the hanging-wall of the underlying thrust fault. Remnants of several abandoned drainage channels and abandoned alluvial fans are preserved within the folds. The westward lateral propagation of folding is also suggested by an increase in relief and exposure of deeper stratigraphic layers across fold segments in the east of the system, implying a greater cumulative displacement in the east than in the west. The preservation of numerous dry valleys across the fold suggests a continual forcing of drainage around the nose of the growing fold, rather than an along strike variation in slip-rate.

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Control of Bedload Sediment Supply Upon Bedrock Incision and River Longitudinal Profile in the Eastern Central Range, Taiwan

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Rivers (drainage areas: 130-620 km2) draining the eastern slope of the Central Range, Taiwan, show distinct erosion/sedimentation histories during the Holocene: some develop fill terraces with abandoned alluvial fans at the river mouths while others do not. We conducted area-slope analyses for these rivers by using 1: 25,000 topographic maps (contour interval 10 m). We found that although underlain by similar types of bedrock, the rivers developing fill terraces all exhibit higher values (> 0.4) of profile concavity, and are generally wider and consist of fewer/lower knickpoints in their downstream parts. This feature is difficult to be explained by differential rock uplift. Rather, the stronger concavity of river profiles could reflect greater supply of bedload sediments that enhance incision in the lower parts of the rivers. In this case, the aggradation of the terrace fills appears to be a short-term phenomenon. Maximal incision occurred when the supply of bedload sediments after the aggradation decreased to a degree, at which the dual roles of bedload sediments acting as abrading tools while insulating underlying bedrock were suitably balanced. We also focused on the Liwu River, where the late Holocene bedrock incision rates are estimated over few centimeters per year. Only the river's largest tributary develops fill terraces connecting to those in the trunk stream. This tributary is more concave than the trunk stream, such that much of the river is lower than the corresponding trunk

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