T32A-0879 1330h POSTER

A Growing Anticline in Tainan City, Taiwan

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Tainan City has been known as an earthquake prone town since the early immigration of the Han people from Mainland China about four hundred years ago. For the purpose of clarifying tectonic activity and paleo-earthquakes in the Tainan City area, we have finished the excavation of three trenches and the drilling of four holes at the so-called Houchiali Fault on the eastern margin of the Tainan tableland. We carefully observed the cores and exposures in the trenches, performed a detailed mapping, and took samples for C-14 dating and other types of analysis. The results show the trench sites are located at a flexure scarp without direct evidence of faulting. But, from the fact of tilting of Holocene sediments to about 50 degrees and the development of a fracture system in the sediments, one may realize that this is without doubt an active structure. We have tested many different models to interpret the observed geologic evidence in the trenches and outcrops, finally determined a growing fault-propagation fold model to be the best interpretation for the Tainan Anticline, while the Houchiali fault is a back-kink or a blind back-thrust type. A diapiric fold had been discussed as possible for a long time by many researchers, but a fault-propagation fold in origin does not contradict with a mud diapiric feature, which was formed during the folding.

Field evidence shows that the main active phase of the Houchiali Fault and the Tainan Anticline would have been after the deposition of the Tainan Formation about two to three thousand years ago. During the active deformation phase, the Tawan Formation onlaped the Tainan Formation, as well as tilted during the folding, thus, beds on higher stratigraphic horizon show lower dip-angle. Estimated from a detailed geologic profile, the horizontal shortening of the anticline is estimated to be 30 meters. The vertical uplift of the Tainan Formation is also about 30 meters. This indicates that the deformation rate has been about 1cm/year both horizontally and vertically over the last three thousand years.

About three hundred years ago, a major uplift event occurred at the trench site area, the ground surface was then subjected to erosion and scouring, and formed an angular uncomformity. After this erosion surface was formed, a major faulting occurred. This event caused ground cracking and the tilting of a tomb (estimated to be 150 300 years old) by about 7 degrees. After this paleo-earthquake event, a fault sag pond was formed, and the lake started to accumulate lacustrine sediments. It was then filled up and subjected to weathering and soil formation. Finally, the trench site was covered by recent fill about ten to twenty years ago.

After reviewing the historic earthquake documents, we suggest that the fissure filling phenomenon on the angular unconformity surface and the tilted tomb may be related to the 1862 Tainan earthquake, which killed more than 300 people in the City and more than 1000 died during the whole event. If we could accept the fault-propagation fold model, we may also suggest that the ramp of the decollement surface underneath the Tainan City could be the initiation point of an earthquake. Therefore, the earthquake hazard potential of the Tainan City should not be ignored. Lacustrine mud and sand deposits above the angular uncomformity have suffered gentle folding and tilting by about 1-2 degrees. This phenomenon should be very recent, and we should pay more attention to monitor it in the future study.

T32A-0880 1330h POSTER

Transtensional tectonics along a major north-south trending fault in the active convergent Taiwan mountain belt

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The southwestern Taiwan is situated on a transition zone between collision (Chinese continental margin and Luzon arc) and subduction (South China sea and Luzon arc). It is mainly characterized by an extensive composite of alluvium plains (piggy back basin and foreland basin), which is bounded to the east by a geomorphically well-expressed N-S trending linear fault, the Chaochou fault. To the east of the fault, the mountains raise abruptly up to more than 2500 meters and are mainly composed of Eo-Miocene argillite, slate, metasandstone and marble. These mountains are the southern termination of the Central Range, the backbone of the Taiwan mountain belt. Former studies had shown that the Chaochou fault to be either a thrust dominated or a major left-lateral strike slip fault, which is within a transpressional tectonic environment because of the oblique convergence of the Eurasian and Philippine Sea plates.

We propose the Chaochou fault and its immediately adjacent areas recently experienced transtensional tectonic movements. A number of outcrop-scale faults, with both strike-slip and normal-slip components, show a predominant NNE to NE extension and/or ESE to SE compression in the eastern side of the Chaochou fault. Strain magnitude and orientation data from slates also show extension in the direction of NE-SW, which is basically perpendicular to the plate convergence vector (azimuth ca 310 degrees). In addition, GPS studies by the Central Geological Survey in the study area clearly show that the Central Range has a component of stretching parallel to the N-S trending Chaochou fault. Importantly, the motion vectors show transtension in the whole area of the southwest Taiwan across the Chaochou fault. The above kinematic data suggest that the major, possibly active Chaochou fault was recently experiencing left-lateral transtensional tectonic movement rather than a previously expected transpressional tectonic movement in the southwestern Taiwan.

The transition from tectonic regimes of transpressional deformation (thrust and strike-slip fault) to recent transtensional deformation (normal and strike-slip fault) in the region of the Chaochou fault may be attributed to the distinctive tectonic setting at the transition of collision and subduction, especially to the present southwestward extrusion of the study area.

T32B MC: Hall D Wednesday 1330h

What Makes a Craton a Craton? II

(joint with GP, S, V, MR)

Presiding: **L Moresi,** CSIRO, Exploration and Mining**; W Mooney,** USGS

T32B-0881 1330h POSTER

What Makes a Craton a Craton

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Cratonic lithosphere is unique in that it can remain tectonically stable and relatively thick over a time scale approaching a billion years. The physical factors that are key to explaining these observations remain to be fully elucidated. As a step toward this goal, we have undertaken a large suite of numerical simulations that explore the physical conditions required to both stabilize cratonic crust and provide longevity for deep, subcrustal cratonic lithosphere. Several potential factors are considered both alone and in unison. These include: 1) Chemical buoyancy of deep cratonic lithosphere, 2) Viscosity of deep cratonic lithosphere, 3) Viscosity of lower cratonic crust, 4) Brittle yield properties of cratonic crust and/or sub-crustal cratonic lithosphere, 5) Presence or absence of mobile belts surrounding cratons. Based on available data constraints, in terms of lithospheric buoyancy and rheology, the simulations do suggest that the buoyancy and/or viscosity of deep cratonic lithosphere in isolation are not the key factors to making a craton a craton. The simulations instead suggest a controlling role for the yield strength of cratonic lithosphere as a whole in providing stability and longevity.

T32B-0882 1330h POSTER

Global variations in density, composition, and thermal regime of continental roots

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We use gravity, thermal, and seismic data to examine how the density and composition of lithospheric roots vary beneath the cratons. Our interpretation is based on the gravity anomalies calculated by subtracting the gravitational effects of bathymetry, topography, and the crust from the observed gravity field, and the residual topography that characterizes the isostatic state of the lithosphere. We distinguish the effects of temperature and compositional variations in producing lithospheric density anomalies using two independent temperature constrains: based on interpretation of the surface heat flow data (Artemieva and Mooney, JGR, 2001) and estimated from global seismic tomography data (Ekstrm and Dziewonski, JGR, 1998). We find that in situ lithospheric density differs significantly between individual cratons, with the most dense values found beneath Eurasia and the least dense values beneath South Africa. This demonstrates that there is not a simple compensation of thermal and composition effects. We present a new gravity anomaly map that was corrected for crustal density structure and lithospheric temperatures. This map reveals differences in lithospheric composition, that are the result of the petrologic processes that have formed and modified the lithosphere. All significant negative gravity anomalies are found in cratonic regions. In contrast, positive gravity anomalies are found in two distinct regions: near ocean-continent and continent-continent subduction zones, and within some continental interiors. The origin of the latter positive anomalies is uncertain.

T32B-0883 1330h POSTER

On the relations between cratonic lithosphere thickness, plate motions, and basal drag

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Seismic and thermal estimates suggest a highly variable thickness of Precambrian lithosphere (140-350 km), with a bimodal distribution for Archean cratons ($\sim$ 220 km and $\sim$ 350 km). We discuss the origin of such large variations in lithospheric thickness and examine mechanisms of lithospheric erosion. Our analysis shows that the horizontal and vertical dimensions of Archean cratons are strongly correlated: larger cratons have thicker lithosphere. The basal drag model of lithosphere erosion (Sleep, 2001) is tested as a means of explaining the present-day bimodal distribution of lithospheric thicknesses of the Archean cratons. In agreement with theoretical predictions, we find that lithospheric thickness in Archean keels is proportional to the square root of the ratio of the craton length (along the direction of plate motion) to the plate velocity. These results show that the basal drag model provides a viable explanation for the variation in thickness of Archean cratonic roots. Basal drag may have varied in magnitude over the past 4 Ga. Higher mantle temperatures in the Archean would have resulted in lower mantle viscosity. This in turn would have reduced basal drag and basal erosion, and promoted the preservation of thick (>300 km) Archean keels, even if plate velocities were high during the Archean.

T32B-0884 1330h POSTER

Heat Flow in the Western Superior Province of the Canadian Shield

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New heat flow and heat generation measurements have been made in deep boreholes (>500m) at several sites in Ontario, northwest of Lake Superior. The new measurements and reevaluation of older data from the International Heat Flow Commission compilation have drastically altered the heat flow map in the Western Superior Province of the Canadian Shield. Previous maps suggested some local high heat flow anomalies (> 60 mW m^{-2}). The new heat flow values between 31 and 46 mW m^{-2} are well within the standard range of values in Archean provinces. The high heat flow values are all from small lake measurements with very shallow probe penetration and extreme dispersion between measurements. On the other hand, high quality marine heat flow measurements in Lake Superior have yielded values within the same range as the land data. After all the heat flow values obtained in shallow lakes have been removed, the Western Superior no longer appears as anomalous on the heat flow map of the Canadian Shield.

T32B-0885 1330h POSTER

Effective Elastic Thickness of the Eastern Canadian Shield

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We have determined the effective elastic thickness of the lithosphere, T_e, in eastern Canada from the coherence between surface topography and Bouguer gravity anomalies. We used three complementary methods to estimate the power and cross spectra: the standard Fourier transform, the maximum entropy method (MEM) and the wavelet transform. The wavelet transform and the MEM yield better spatial resolution than standard Fourier methods. For MEM and Fourier transform methods, T_e is estimated over areas 508 × 508 km. The standard Fourier method is used to control our results. The study shows important variations in elastic thickness in eastern Canada where it ranges between 30 and 100km. In the eastern part of the Superior province, the elastic thickness is large (T_e > 80 km). Previous studies have shown that the central and western parts of the Superior also have large values of T_e. In Labrador, the Nain province (the Canadian fragment of the North Atlantic craton) also seems to have high T_e. This result differs from those of previous studies suggesting lower T_e near the edge of the continent. This difference may be because our calculations exclude the transition to the continental margin. Between the New Quebec and the Torngat orogens, the core zone has lower T_e ($\approx$ 30 $\rightarrow$ 60 km) decreasing toward the Grenville front. Low values of the elastic thickness are also inferred for the Ungava Peninsula south of the Cape Smith Belt. Over the entire Canadian Shield, values of T_e show no correlation with heat flow. Also, there is no clear geographic trend relating T_e and the distance to the edge of the craton. Changes in elastic thickness are more likely related to varying crustal composition.

T32B-0886 1330h POSTER

Geophysical Investigation of Salt Tectonics and Deeper Structure in the Eastern Magdalen Basin, Atlantic Canada.

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Magnetic anomalies and related salt structures in the E. Magdalen basin give a window in to the effects of regional tectonics on basin formation. The Magdalen basin contains up to 18 km of Paleozoic sedimentary rocks resting on the crystalline basement of the Acadian Orogeny. Carboniferous rocks are intensely deformed as a result of regional faulting and salt tectonism, which was initiated following deposition of the Viséan Windsor Group. Clusters of short wavelength magnetic lineations, associated with gravity anomaly lows, define NNE and ENE trending linear belts, which enclose rhomboidal zones of very low amplitude magnetic anomalies. Seismic profiles show the lineations to be related to zones of deformation and diapir collapse near to the margins of the salt structures. Euler deconvolution models indicate both shallow (<300 m) and deeper (<1 km) fault or contact type magnetic sources. Shallow sources are interpreted to result from mineralisation associated with alteration in salt impregnated iron rich sedimentary rocks, brecciated during salt activity. Deeper sources are related to faulting and are linked to the deeper structure. The base event, the deepest regionally mappable seismic horizon at between 2-5 s. TWTT (~ 5-11 km), is associated with an unconformity at the base of the Windsor Group, sampled by the Cap Rouge well. Salt structures are related in both trend and location to faults and associated topographic highs in the base event.

The orientations of structures in the eastern Magdalen basin are generally consistent with regional deformation associated with middle Carboniferous dextral strike-slip motion on the E trending Cobequid-Chedabucto fault system. As suggested by the strain ellipse model, this produced NW compression and ENE dextral motion in the E. Magdalen basin from Viséan to at least Westphalian D. This resulted in thrusting of the base event to the SE of the Magdalen Is. and NE of Cape Breton Is. and dextral motion on faults which bound the southern edges of rhomboidal structures.

T32B-0887 1330h POSTER

Structure of the Crust and Upper Mantle Beneath the Canadian High Arctic From Analysis of Broadband Teleseismic Waveforms.

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In summer 2000, seven three-component broadband seismic stations were deployed in small communities across the Canadian High Arctic and western Greenland, adding to the existing sparse network of broadband stations. The increased station density allows us to investigate the seismicity of the region and the crust and upper mantle structure in more detail than has previously been possible.

For each seismic station, a data set of P waves is used to generate teleseismic receiver functions. These are used to model the one-dimensional shear wave velocity structure of the crust beneath each station. The models show significant variation in the thickness and nature of the crust across the region. In the south and east, the crustal structure is relatively simple, with Moho depth ranging from 35 km to 45 km. Further north and west, the crust thins, with a minimum Moho depth of 25–30 km below the northernmost seismic station (ALE). The structure beneath the western Arctic stations is complex, with azimuthal variations indicating three-dimensional structures and/or anisotropy.

Deeper structure is investigated using Rayleigh wave phase velocity analysis. Dispersion curves are generated for paths between pairs of stations, for Rayleigh wave periods ranging from 20 to 120 seconds. These dispersion curves are inverted to obtain the average shear wave velocity structure in the upper mantle along each station-station path. Preliminary analysis of the long-period phase velocities shows close agreement with the results of *Brune & Dorman (1963)* for several of the Arctic paths.

We combine the results from the receiver function analysis, Rayleigh wave dispersion analysis, and previous published seismic studies to give new information about the variations in structure across the Canadian High Arctic.

T32B-0888 1330h POSTER

Regional Teleseismic Tomography of the Lithosphere Beneath the Murray Basin, SE Australia

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From March till July 1999 a portable array of 40 short period digital seismograph stations was operated across the border of Victoria and South Australia, covering the south-western part of the Murray Basin, and the southern part of the early Paleozoic Delamerian Orogen. The Murray Basin 1999 (MB99) survey forms the second stage of a major seismological project in SE Australia, which was jointly operated by Monash University and Adelaide University between 1998 and 2000. Consisting of five approximately W-E oriented receiver lines, the MB99 array measured about 2° in latitude by 3° in longitude. The main aim of the MB99 project is to map lateral variations in P-wave speeds (Vp) in the lithosphere just east of a major geological boundary (the so-called Tasman line) between the Proterozoic cratons of central Australia, and the Paleozoic Tasman orogenic belt of eastern Australia, using regional teleseis mic arrival time tomography. The highly active margins of the Australian plate provided the majority of the observed events. More than 6000 arrival times from about 170 teleseismic events were inverted for a minimum structure Vp model in the upper few 100's km using a non-linear inversion scheme and 3-D ray tracing. The most prominent positive anomaly (up to 2.5%) in Vp is found at relatively shallow depths (about 30-100 km) underneath the western part of the Murray Basin, in a coherent volume striking approximately parallel to the coastline. Crustal thinning toward the edges of the Australian continental shelf might account for a small fraction of the observed negative residuals, but the overall pattern of relative arrival time residuals, which changes strongly with back azimuth, does not suggest such a shallow high speed anomaly. A pronounced negative anomaly (about 1.5-2%) is located north of the centre of the array. Little a priori information from seismic profiling is available.

(first author now at CTBTO PrepCom, Vienna International Centre, Vienna, Austria)

T32B-0889 1330h POSTER

The Lithospheric Structure of the Eastern Alps

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Recent results of the seismic profile TRANSALP initiated new investigations of the lithospheric density structure in the Eastern Alpine area. By combining seismic results with geological models, tomographic studies and other available information the 3D density structure were modeled according to the Bouguer anomaly field and geoidal undulations.

Two different models were produced, regarding the question of defining a common crust-mantle boundary in gravity and seismic/tomographic studies. The seismic crust-mantle interface shows a depth of some 40 km in the Adriatic area, leading to lower crustal thickness of around 10 km, while the "gravity Moho" points to a depth of around 30 km. In the northern European foreland the crustal thickness in both models is around 30 km.

Main common features of these models are, that the upper, near surface structures, which can easily connected to surficial tectonic regime, give an amount up to 30% of the connected Bouguer anomaly, and that there are indications for a sublithospheric density inhomogeneity which strongly affects the potential fields in addition to lithospheric domains.

The modeled density structures can now be used to derive the internal lithospheric stresses and its distribution provides insights into the processes acting at the European and Adriatic plate interface.

Finally this density structure modeling provides information of the isostatic behavior of the Eastern Alps, which are probably not in isostatic equilibrium and show great isostatic anomalies in the sense of Airy isostasy. Therefore a more regional compensation (Vening-Meinesz isostasy) has to be regarded, what for the elastic lithospheric thickness (Te) has to be calculated. This Te is connected to the topographic and crustal, internal loads and their distribution. The density model indicates that the subsurface loads of the Alpine crust are as important as the loads by the topography.

URL: http://userpage.fu-berlin.de/~wwwgravi/gravi_ag/mitarbeiter/jebbing/Transalp.html

T32B-0890 1330h POSTER

Flexural rigidity and lithospheric stress in collisional orogens from constrained 3D density models

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3D modeling of gravity and terrain reduced geoidal undulations have been carried out in the interdisciplinary research groups of the European TRANSALP consortium and the German-South American "Collaborative Research Center 267" (Deformation Processes in the Andes) to provide insight into the structure of the lithosphere in the areas of the Alpine-Adriatic (African) and Pacific collision zone, respectively.

The density models are well constrained by modern seismic imaging and other geophysics. In particular the model resolution of superficial crustal structures is sufficient to calculate gravity effects and the subsurface loads. Both are used to calculate lithospheric flexural rigidity and/or effective elastic thickness from the gravity field and the geoid by the aid of two methods: (1) coherency function for the Andes and (2) convolution for Alps and Andes. The aim of this poster is to compare the results of the two methods and demonstrate the advantage of the convolution over the coherency method. Although the results of flexural rigidity are rather similar we figures out that convolution overcomes a series of numerical problems we have with the coherency method.

The regional tectonical environments of Andes and Alps clearly differ from each other which is reflected by different pattern of flexural rigidity. For maps rendering of flexural rigidity (effective elastic thickness of the lithosphere) from topographic and subsurface loads we obtained for the Western South American Continental margin and the high Andean plateau low values (10 E22 to 10 E23 Nm) for Central Andes and 10 E23 to 5x10 E 23Nm in the continental back arc region which corresponds with an effective elastic thickness of 35 to 45 km. In the case of the Alps rigidity/effective elastic thickness was calculated only by the convolution method. Here the flexural rigidity shows small values (10 E21 Nm) and correlates clearly with the crust-mantle boundary and the shape of the orogen.

In a last step we used the curvature of lithospheric layers of our 3D model to calculate the stress distribution which is produced by flexured layers. First results can show that the main stress is connected with the crust-mantle boundary and the transition zones of the different plates, however, additional patterns can be seen which were correlated with the results of Vp-tomography and the distribution of electrical conductivity (volcanic arc and forearc areas in the Andes) and in the Eastern Alps abnormal stress is caused by crustal domains in the area of the Vicenza gravity high.

T32B-0891 1330h POSTER

Seismic Evidence for Late Proterozoic Orogenic Structures Below Kattegat, SW Scandinavia

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The exposed Grenville-Sveconorwegian crustal provinces of the Baltic Shield in southwestern Sweden and southern Norway are delimited along the Kattegat and Skagerrak coasts. To the southwest the continuation of the late Precambrian basement is masked by Phanerozoic sediments of the Kattegat-Skagerrak platform and the Danish-Norwegian basin. Within the last 25 years hydrocarbon exploration in Kattegat and Skagerrak has generated several marine reflection seismic surveys. We have used this data to correlate the exposed orogenic structures of southwestern Sweden with the seismically observed basement structures in Kattegat and Skagerrak. Borehole data, deep seismic profiles and potential field data are used as well. Interpretation of the reflection seismic lines shows that the reflectivity of the basement is dominated by bundles of dipping reflections down to to 6 s twt. Correlation of the reflection bundles show that they can be divided into two groups; (1) W dipping and (2) SE dipping reflections. The W dipping reflection bundles are interpreted to represent the southwestward continuation of the Sveconorwegian ductile shear zones exposed in SW Sweden. The SE dipping reflections represent older, possibly Gothian, compressional structures that became partially overprinted by the later Sveconorwegian Orogeny. The subcrop of some of the prominent bundles of dipping reflections trends close to faults in the sedimentary cover. This may indicate that some of the interpreted late Proterozoic shear zones were reactivated during the subsequent basin formation and inversion in the Danish area.

T32B-0892 1330h POSTER

East European Craton Margin Source for the Allochthonous Northern Terrane of Taimyr, Arctic Siberia

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The Taimyr Peninsula, Arctic Siberia, comprises two allochthonous terranes, the Northern and Central terranes. The ultimate origin of these terranes remain controversial. Provenance investigations of detrital zircon populations (U-Th-Pb ion-microprobe analyses) were undertaken in order to determine geologic affinities and, thereby, the source of the Northern terrane.

The Northern terrane comprises rhythmically interbedded Neoproterozoic to Cambrian (inferred from acritarchs) sandstones, siltstones, and pelites. These sediments are interpreted to represent turbidites formed on a continental slope. These grade into Ordovician-Devonian and early Carboniferous limestones and dolomites, reflecting the progression to a deeper water depositional environment. In the middle Carboniferous, the deposition of terrigenous sandstones, argillites, and coal indicates the proximity of land subjected to erosion and to lagoonal conditions of sedimentation. In addition, Carboniferous Uralian deformation resulted in regional greenschist and amphibolite facies metamorphism of the Northern terrane under moderate pressure and moderate- to high-temperature conditions. The change in sedimentary environment in conjunction with deformation, both of Carboniferous age, is thought to reflect the onset of Uralian orogenesis and the accretion of the Northern terrane to Siberia. Permian (264 Ma) post-collision granitic intrusions define the end of Uralian orogenesis in the northern regions. In the western Northern terrane these relationships are obscured due to contact metamorphism associated with Permo-Triassic (245 Ma) anorogenic plutonism.

Detrital zircons from two greywacke samples of the easternmost Northern terrane indicate that late Neoproterozoic/Cambrian sediments contain rather limited age populations mostly between ca. 550 and 700 Ma, with pronounced cummulative frequency peaks in both samples at ca. 560 Ma. Such ages are not endemic to northern Siberia, confirming the allochthonous nature of the Northern terrane. Furthermore, 560 Ma ages are well known from subduction related granites intruding basement lithologies of the Pechora Basin, suggesting that latest Neoproterozoic/Cambrian sediments of the Northern terrane were derived from the erosion of the eastern margin of the European craton (Baltica). Uralian orogeny, suturing Baltica to Siberia, began to the south in the early Carboniferous and thereafter progressed northwards. Uralian orogenesis had ended in Taimyr by the late Carboniferous. Thus, the Northern terrane was 'accreted' to Siberia by the early Permian. In summary, the Northern terrane likely represents a sliver of Baltica proximal to the Pechora basin in the latest Neoproterozoic/Cambrian when the sediments were deposited; it was then sutured to Siberia during the collision between Baltica and Siberia in the late Carboniferous. This suturing was likely via dextral transpression, consistent with last-motion structural data of pre-Permian age.

T32B-0893 1330h POSTER

Mantle Flow Modeling of the Anomalous Subsidence of the Silurian Baltic Basin

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Over the last decade there has been an effort to reconcile a number of enigmatic episodes of large scale basin development in terms of the dynamic response of the lithosphere-crust to mantle flow linked to plate subduction. In this paper we apply this philosophy to consider the anomalous long-wavelength component of sediment deposition within the Silurian Baltic Basin that has been inferred in recent reconstructions [Poprawa et al., *Tectonophysics,* 1999]. This deposition extends over 400 km beyond foreland basins predicted on the basis of supracrustal loading in the region; it has been suggested that the discrepancy may be due to dynamic topography supported by mantle flow coupled to Silurian plate subduction. We test this suggestion using mantle convection simulations, and find that dynamic topography is capable of fully reconciling the far-field deposition. These simulations constrain the paleo-dip of the subduction to $45^{\circ}-65^{\circ}$, with the range reflecting an uncertainty in the location of the paleo-trench. We furthermore demonstrate that this mantle loading component provides 50-90% of the reconstructed near-field deposition. This result indicates that the slab-induced mantle flow mechanism is an important contributor to the development of the foreland basin.

T32B-0894 1330h POSTER

Moho-offset beneath the western margin of Lake Biwa, Japan, deduced from gravity data and short-period receiver function imaging: Who is pulling down the crust beneath the lake?

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We discuss subsurface density structures and some problems regarding isostasy in and around Lake Biwa in the Kinki district, Japan. Lake Biwa is the most largest lake in Japan. The Paleo Lake Biwa can be traced back to almost 4 million years ago. The lake region is characterized by strong negative Bouguer anomalies. Especially, a steep horizontal gradient zone of gravity anomaly field is distributed along the western margin of the Lake. The large amount of the gravity anomaly depression (>50mgals) can not be explained only by low-density sediments beneath the lake. This large gravity depression indicates that a down-warping structure extends to the Moho depth. This conjecture has been strongly supported by short-period receiver function imaging. Moho discontinuities derived from the imaging shows the clear offset of about 8km under the steep gravity gradient zone.

A question arises as what is the driving force to create such large down-warping structure against isostatic buoyancy? We consider that the subduction of shallow slab under the region (Philippine Sea Slab) may affect to the crustal deformation through the high-viscous fluid between them. In order to confirm this speculation, we simulated the induced mantle flow and the pressure distribution due to the subduction of the Philippine Sea Slab. This numerical experiment has provided a result that the induced flow makes a negative pressure zone under the lake region, when the slab has an offset beneath one side of the region. This offset of the slab coincides with some plate models deduced from hypocentral distributions and/or Sp phases of the deep-focus earthquakes.

T32B-0895 1330h POSTER

Collapse and Melting in a Confined Orogenic Belt: Preliminary Results From the Neoproterozoic Araçuaí Belt of Eastern Brazil

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The Neoproterozoic Araçuaí belt of eastern Brazil records the closure of a Red Sea-type basin between

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the São Francisco and Congo cratons of West Gondwana, and is part of the Brasiliano (Pan-African) orogenic system. In its southern part this basin contained oceanic crust, so that closure involved subduction and arc magmatism prior to continental collision. In its northern part, the basin was entirely ensialic. After the cessation of subduction, a period of magmatic quiescence and possible plateau development ended with the collapse of the orogen. Extensional structures are observed across the preserved Brazilian portion of the orogen (the eastern segment of the orogen is now in West Africa). Six distinct syn- to post- kinematic granite suites were emplaced within the orogen, although the temporal relation of the different granite suites to contractional and post-collision extensional tectonism has remained enigmatic. Preliminary U-Pb ages for key granite suites are related to the structural history of the orogen, placing important constraints on the timing and duration of orogenic collapse.

The age of the northernmost pluton of the subduction-related (G1) granite suite is consistent with published ages for this suite of 625 to 575 Ma. The G2 suite consists of an anatectic sea of variably foliated S-type migmatitic leucosomes, leucogranitic sheets and plutons, commonly associated with locally extensional mesoscopic shear zones. This migmatite-leucogranite association covers >75% of the outcrop over an area of ∼20,000 km^2. A preliminary U-Pb zircon age of ca. 536 Ma from a well-foliated G2 pluton is significantly younger than published ages from other G2 bodies (590 to 570 Ma). Bodies sampled from the other suites are: an I-type granite showing flow foliation but little or no tectonic fabric (G3I suite), an undeformed S-type leucogranite (G4 suite), and an undeformed I-type granite containing dioritic enclaves (G5 suite). Preliminary U-Pb zircon ages from all three are within error and slightly younger than the age of G2, consistent with published ages from other G4 and G5 bodies.

The new younger age of at least some G2 granites alleviates a major problem in the tectonic evolution of the Araçuaí belt, which was the association of these granites with extensional shear zones apparently at ca. 590 to 570 Ma (a time when subduction-related magmatism, and presumably crustal thickening, were still active). If widespread generation of S-type migmatites, sheets and plutons in fact occurred at ca. 530 to 540 Ma, part of this suite can instead be related to orogenic collapse (the older S-type bodies may be related to syn-collisional magmatism). Since the body we sampled is well foliated, the intrusive age gives an upper limit for the onset of extensional fabric development in this location. The presence nearby of unfoliated G4 and G5 plutons intruded only a few m.y. later restricts collapse to a relatively short period.

T32B-0896 1330h POSTER

Olmecan and Zapotecan tectonothermal events in the northern Oaxacan Complex, southern Mexico: constraints on Rodinia reconstructions.

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Inliers of ca.1-1.3 Ga rocks occur throughout Mexico and Honduras and form the basement of Oaxaquia and the Chortis blocks. The largest inlier occurs in southern Mexico, where ca. 1 Ga rocks of the Oaxacan Complex consist of para- and orthogneisses, with U-Pb protolith ages between ca. 1,350 and ca. 1,010 Ma. These rocks were affected by two major tectonothermal events, named Olmecan and Zapotecan, respectively. Olmecan event, which occurred at ca. 1,100 Ma, produced rootless refolded folds and migmatites in the dioritic-gabbroic protolith of the lower structural slice. Intrusion of an anorthosite-mangerite-charnockite-granite suite at ca. 1,010 Ma predates the Zapotecan orogeny dated at ca. 990 Ma. The Zapotecan orogeny produced at least 3 sets of NNW-trending coaxial folds accompanied by granulite-facies metamorphism. Fold mechanisms include flexural and tangential-longitudinal strain (TLS) accompanied by intense flattening and stretching parallel to the fold axes. A set of ca. 980 Ma late tectonic pegmatites that is contemporaneous with clinopyroxene hydration to form hornblende, is refolded by steeply inclined, N-trending, gently dipping TLS folds. Subsequent deformation includes: (1) low-angle, top-to-SE, shearing at lower amphibolite facies; (2) gently NNW-plunging, upright to steeply inclined, NNW-trending flexural folds; and (3) top-to-E-ENE shearing during Late Paleozoic, greenschist facies metamorphism. The Zapotecan orogeny is contemporaneous with: (1) the main tectonothermal event recorded in other Mexican inliers; (2) the ca. 1060-985 Ma Sveconorwegian orogeny, (2) the ca. 980 Ma tectonothermal event in the Colombian massifs, (3) the ca. 970 Ma Mollendo tectonothermal event in the Arequipa massif of Peru, and (4) the tectonothermal events in some Appalachian Grenvillian massifs, such as Blair River Complex and Goochland terrane. This suggests that Oaxaquia shared a common history with these ca. 1 Ga massifs and that they may have been involved in the collisions that led to the amalgamation of Rodinia.

T32B-0897 1330h POSTER

Achaean Continental Crust Under the Pan-African Orogenic Belt, East Antarctica

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Lützow-Holm Complex, located in East Antarctica, is a Cambrian collision zone between Achaean craton (Napier Complex) and Dronning Moud Land, where occurs the upper amphibolite- to granulite-facies rocks, and it is regarded as a part of the Pan-African orogenic belt during Gondwana continent amalgamation. The exhumation of the granulite-facies rocks with clockwise P-T path has been attributed to extensive surface erosion (up to 30 km thick) of double-thickened crust, but the common belief that higher-pressure garnet bearing rocks e.g. high-pressure granulites and/or eclogites exist at deeper level of crust is not supported by geophysical data. In this paper we reconstruct crustal structure beneath Lützow-Holm Complex by combining ultrasonic velocity of rocks with seismic velocity structure. Consequently our results suggest that Achaean continental crust (lower pressure) exists under the Pan-African Orogenic Belt (higher pressure), and propose a new tectonic model for exhumation of the granulite-facies metamorphic belt instead of the double-thickened crust model.

P-wave velocity (Vp) in ultra-high temperature granulites (UHT) was measured up to 1.0 GPa from 25 to 400 with a piston-cylinder-type high-pressure apparatus. Rocks measured are meta-igneous UHT rocks collected from Mount Riiser-Larsen, Enderby Land, East Antarctica where the Achaean Napier Complex occurs. Core rock samples with 14mm diameter and 12mm long were subjected to high-pressure experiments. All rocks show a rapid increase of Vp at low pressure up to 0.4 GPa and nearly constant Vp at higher pressures. The Vp values measured at 1.0 GPa and 400 are 7.17 km/s for a meta-pyroxenite, 6.93 km/s, 6.88 km/s for mafic granulites and 6.17 km/s for an orthopyroxene felsic gneiss.

The Vp values measured for the Napier mafic granulites are comparable to the lower crustal layer (6.95 km/s of Vp at depth from 33 to 40 km) under the Lützow-Holm Complex. The present results suggest that the lower crust is composed of garnet-free orthopyroxene-clinopyroxene-plagioclase granulites rather than garnet granulites or eclogites. It means that the lower pressure granulite-facies metamorphic body (Achaean Napier Complex) underlie the higher-pressure granulite-facies metamorphic belt (Cambrian Lützow-Holm Complex). The double-thickened crust model can not explain the lower metamorphic pressure at deeper level. We suggest that the Lützow-Holm Complex was once subducted beneath Dronning Moud Land during continental collision between the Napier Complex and Dronning Moud Land and subsequently was extruded onto the Achaean Napier Complex after the collision. Rheological data strongly suggest that the Lützow-Holm Complex were extruded rapidly from about 30 km depth. Our interpretation implies that granulite-facies orogenic belts with clockwise P-T path are not necessarily exposed double-thickened crusts but extruded crusts.

T32B-0898 1330h POSTER

Crustal Structure From Receiver Functions Analysis in Northern Victoria Land

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The Transantarctic Mountains (TAM) form one of the Earth's mayor interplate mountain belts. Evolution of TAM reflects regional- and global-scale processes. Understanding TAM uplift history and linkage to geophysical model requires the knowledge of crustal and upper mantle structure.

Teleseismic body waveforms have often been used to infer crustal geometry beneath isolated seismic stations. In this study we model Receiver Functions (RFs) obtained from teleseismic P waveforms recorded at various antarctic broad-band seismic station deployed during four austral summer campaigns (1993-98,2000-01) in Terra Nova Bay (TNB) region and Rennick and Lillie Glaciers (RLG) area.

We recorded several hundreds of teleseismic events (more than 200 for a single station) with magnitudes between 5.0 and 7.2 getting good azimuthal coverage. RFs are performed through frequency-domain deconvolution, following the approach developed by Di Bona (1998). This method is used in order to evaluate RFs variance and the actual noise level involved and allows to use small magnitude events (Mb=5.0) generally excluded from RFs analysis. RFs azimuthal characteristics, for each stations, were analyzed and best RFs from different azimuth were inverted for fine crustal structure following the inversion scheme of Sambridge (1998).

Results show Moho-depth coherence with previous studies in TBN region. As no previous studies exist for RLG area, our results are original for RLG and of general interest for Antarctic.

T32B-0899 1330h POSTER

Transition From Archean Plume-Arc Orogens to Phanerozoic Style Convergent Margin Orogens, and Changing Mantle Lithosphere

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Mantle plume activity was more intense in the Archean and komatiite-basalt volcanic sequences are a major component of many Archean greenstone belts. Tholeiitic basalts compositionally resemble Phanerozoic and Recent ocean plateau basalts, such as those of Ontong Java and Iceland. However, komatiite-basalt sequences are tectonically imbricated with bimodal arc lavas and associated trench turbidites. Interfingering of komatiite flows with boninite series flows, and primitive to evolved arc basalts has recently been identified in the 2.7 Ga Abitibi greenstone belt, demonstrating spatially and temporally associated plume and arc magmatism. These observations are consistent with an intra-oceanic arc migrating and capturing an ocean plateau, where the plateau jams the arc and imbricated plateau-arc crust forms a greenstone belt orogen. Melting of shallowly subducted plateau basalt crust (high Ba, Th, LREE) accounts for the areally extensive and voluminous syntectonic tonalite batholiths. In contrast, the adakite-Mg-andesite-Niobium enriched basalt association found in Archean greenstone belts and Cenozoic arcs are melts of LREE depleted MORB slab. Buoyant residue from anomalously hot mantle plume melting at > 100km rises to couple with the composite plume-arc crust to form the distinctively thick and refractory Archean continental lithospheric mantle. New geochemical data for structurally hosted ultramafic units along the N. American Cordillera, from S. California to the Yukon, show that these are obducted slices of sub-arc lithospheric mantle. Negatively fractionated HREE with high Al_2O_3/TiO_2 ratios signify prior melt extraction, and variably enriched Th and LREE with negative Nb anomalies a subduction component in a convergent margin. A secular decrease of mantle plume activity and temperature results in plume-arc dominated geodynamics in the Archean with shallow subduction and thick CLM, whereas Phanerozoic convergent margins are dominated by arc-continent, arc-terrane, and terrane-terrane collision with steep subduction resulting in narrow belts of granitoids and obduction of lithospheric mantle.

T32B-0900 1330h POSTER

Thermo-tectonic Modelling for the South Urals: High Paleo-heat flow, Multi-stage Exhumation, and Possible Ultrahigh-pressure Metamorphism

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Two-dimensional numerical modelling of the HP-UHP Maksyutov Complex in the south Urals answers questions about thermal conditions during eclogite-facies metamorphism, exhumation rates, and whether UHP metamorphism is thermally possible within existing time constraints. Thermal boundary conditions used for modelling are based on the P-T-t evolution of the eclogitic unit of the Maksyutov Complex from previous thermobarometric and geochronologic data. Best fit models are obtained with initial surface heat flow of 70 mWm-2, not the low present-day values. Onset of subduction in the south Urals probably occurred between 410 and 393 Ma. High-pressure eclogite-facies metamorphism was modelled at 380 Ma. Exhumation rates for the eclogites to mid-crustal levels are up to 7 mm/a if blueschist-/greenschist-facies metamorphism occurred at 375 Ma; if younger ages for this metamorphism are assumed (360 Ma), rates drop to about 1.7 mm/a. Final exhumation rates from mid- to shallow-crustal levels range from 0.2 to 0.3 mm/a. Previous work has shown there is a possibility of UHP metamorphism pre-dating the HP metamorphic event; modelling shows that a UHP event at 385 Ma fits well within the time frame of arc-continent collision in the south Urals as constrained by geological and isotopic data. Exhumation from UHP to HP conditions would have been faster initially (9.2 mm/a) and followed by a long relaxation period (25 m.y.) at eclogite-facies conditions; this relaxation period would have provided the time and heat required to transform any UHP index minerals to their low-pressure pseudomorphs.

T32B-0901 1330h POSTER

Wavelet transform mapping of effective elastic thickness and plate loading

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We present a new wavelet transform method to map spatial variations in effective elastic thickness T_e and plate loading ratio f. The method assumes a model of thin plate flexural isostasy to describe the mechanical response of the lithosphere to vertical loading. In this model, the rheological properties of the lithosphere are aggregated into the effective elastic thickness T_e of an equivalent thin plate overlying an inviscid fluid. A number of methods have been developed to map spatial variations in T_e in an attempt to assess regional patterns of flexural strength. Our new method first obtains local coherence and local admittance through wavelet cross-spectral analysis of surface topography and Bouguer gravity anomaly. Wavelet coherence is used to obtain the local characteristic wavelength, which is a function of both T_e and the degree of relative loading f of the plate by sub-surface loads and surface loads (loading is the combined effect of erosion, sedimentation, intrusion, faulting and metamorphism). Wavelet admittance is converted into local pseudo-coherence and is used to resolve this f-T_e ambiguity. We carry out extensive tests of the wavelet method on simulated topography and Bouguer gravity anomaly data, that we generate through finite difference simulations of flexural isostasy with spectrally realistic loads and simple spatial variations in T_e. These tests demonstrate that the wavelet inversion method is reasonably robust to uncertainties in loading and in crustal thickness, and is able to recover the correct values and patterns of T_e to within ± 5 km. We apply the wavelet method to southern Africa and recover estimates of T_e principally in the range $25 - 50$ km, in good agreement with existing estimates from forward modeling and Fourier coherence analyses. The relationship of the apparent variations in T_e and plate loading to regional tectonics are discussed.

URL: http://geomorph.ldeo.columbia.edu

T32B-0902 1330h POSTER

Relationships Between the Kern Canyon Fault (KCF) and the Prot-Kern Canyon Fault (PKCF), Southern Sierra Nevada, CA.

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The PKCF is an intra-arc shear zone which accommodated several tens of kilometers of Late Cretaceous dextral displacement during oblique convergence between the North American and Farallon plates. It is expressed for ca. 90% of its ca. 130 km length as a 1-2 km wide zone of mylonitization centered along a transposed intrusive contact with pendant rocks both as a function of distance from the contact and rock type: Marbles and pelites are pervasively deformed with crystal plastic fabrics, while impure and pure quartzites and amphibolites are domainally sheared with vestigial lenses preserving earlier deformation, metamorphism, and primary features. The east-bounding granitic intrusives are pervasively mylonitic for up to .51 km, with the youngest phases (85-80 Ma) exhibiting syn-magmatic shear fabrics. Much of the batholithic rock to the west of the shear zone-hosting pendant is Early Cretaceous in age and shows localized brittle-ductile shear bands related to the PKCF. We interpret these relations to indicate that Late Cretaceous ductile shearing was localized along a high ductility contrast zone between older far subsolidus batholithic rocks to the west and solidus to near subsolidus intrusions to the east. The northen half of the PKCF also exhibits a brittle phase of dextral shear localized primarily along the pendant - Late Cretaceous batholith contact zone. In the Kernville area this brittle shear zone/fault is shunted southwestward into the KCF. Timing of this brittle phase of dextral shear is poorly constrained, but is thought to be latest Crtetaceous - Paleocene(?). Busby-Spera and Saleeby (1990) suggested a minor component of East side up motion of the PKCF. Recent field investigations indicate West side up normal faulting remobilization of the KCF and its northward extension into the PKCF has occurred in Quaternary time. The down-dip projection of the normal fault structures intersects the Durrwood Meadows hypocenter swarm of extensional earthquakes (Jones and Dollar, 1986).

T32B-0903 1330h POSTER

Provenance of Cambrian Sandstone in Southern Israel: SHRIMP Dating of Detrital Zircons

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Phanerozoic silisiclastic detrital sequences cover large parts of NE Africa and Arabia. East of the Nile, including in southern Israel, thick Phanerozoic siliciclastic sequences (often referred to as Nubian sandstones) rest upon the Pan-African crystalline basement of the Arabian-Nubian Shield (ANS) that was deeply eroded at the end of the Neoproterozoic. This late to post Pan-African unroofing is a logical source for the thick Phanerozoic sequence that was deposited over the northern Gondwana margin, but previous U-Pb geochronology of detrital zircons in northern Africa yielded Middle Proterozoic ages (pre-Pan-African).

In southern Israel, Middle to Late Cambrian sandstone unconformably overlies the Late Precambrian crystalline basement of the ANS. U-Pb SHRIMP measurements were performed on 230 zircon grains from 4 samples taken from different startigraphic levels of the Cambrian of southern Israel.

In contrast with previous studies, our data reveal ubiquitous Pan-African detritus in these rocks. The Cambrian section contains an important contribution (more than 80%) of individual zircons that yield concordant 206Pb/238U ages between 530-950 Ma. These grains are idiomorphic to slightly rounded, typically showing oscillatory, euhedral concentric Cl zoning. They were derived from a Pan-African terrain, most probably from the ANS. Our analyses also revealed the presence of a small proportion of pre-Pan-African zircons, Early and Middle Proterozoic ages: 1.8-1.9 and 2.65-2.7 Ga. in the same Cambrian section. Because the Arabian-Nubian Shield is generally considered to be juvenile Pan-African crust, the provenance of pre-Pan-African zircons should a priori lie at the shield's margins or outside it. However, the shape of these ancient zircon grains does not differ significantly from the Pan-African zircons we dated, suggesting that a distal provenance outside the ANS may not be indicated. Pre-Pan-African crust has been reported in isolated parts of the ANS and it is thus possible that the pre-Pan-African zircons were derived from terrenes similar to these.

Our work has shown that the Cambrian section in Israel contains abundant Pan-African detritus, whereas previous studies showed that Ordovician and younger siliciclastic sequences in northern Africa were derived from a Middle Proterozoic source. Previous preliminary data suggest that it is reasonable to assume that the post-Cambrian section in Israel is also dominated by pre-Pan-African detritus. If this is correct, the end of the Cambrian marks the end of erosion of the Pan-African orogen in NE Africa.

T32C MC: 309 Wednesday 1330h

Hotspot-Ridge Interactions II *(joint with OS, S, V)*

Presiding: **J Lin,** Woods Hole Oceanographic Institution**; J Dyment,** Universit de Bretagne Occidentale

T32C-01 1330h

Jan Mayen, related to ridge-transform-plume or ridge-transform interactions?

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Jan Mayen, an active volcanic island in the North Atlantic (71N), is located at the Jan Mayen fracture zone that separates the ultra-slow spreading Kolbeinsey and Mohns ridges. The volcanic island has been interpreted to form above a mantle plume, to be related to the Icelandic plume, to result from leaky transform volcanism, or to have formed by southward propagation of the Mohns ridge into a microcontinent situated south of the Jan Mayen fracture zone. The location of the southernmost segment of the Mohns ridge has been poorly defined, and the relation between the ridge and volcanic island volcanisms has therefore been unclear. Dredge sampling and ROV survey followed multibeam mapping of the Jan Mayen region and the Mohns ridge during two cruises in the summer of 2001. These surveys demonstrated that the neovolcanic zone of the Mohns ridge intersects the Jan Mayen fracture zone about 60 km east of Jan Mayen. Mapping and dredge sampling demonstrated also that Jan Mayen does not extend north of the Jan Mayen fracture zone. The volcanic island does therefore not define the southernmost tip of the Mohns ridge, and is not related to propagation of this ridge across the fracture zone and into the margin of a micro-continent located south of the fracture zone. Bathymetry and lineament analyses suggest that the northern, and highly active part of the volcanic island may represent a very short spreading segment within the fracture zone. Submarine lava flows from the northern part of Jan Mayen, and the southern segments of the Mohns ridge were systematically dredge sampled. Elemental and isotopic compositions of these basalts will be reported and discussed in terms of Jan Mayen being related to ridge-transform-plume or just ridge-transform interactions, and the influence of the Iceland plume on the Arctic ridges.

T32C-02 1345h INVITED

Mantle Discontinuity Structure Beneath Iceland

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Receiver functions derived from teleseismic body waves recorded in two broadband seismic experiments in Iceland reveal shear waves converted from compressional waves at mantle discontinuities near 660-, 410-, 330-, and 200-kilometer depth. The transition zone

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