The data quality from the ocean-bottom seismometers is excellent, with first arrivals to at least 75 km offset, and past 100 km on many instruments. Land seismometers also produced excellent results- first arrivals are typically observed out to 200 km offset. Pg/Pn crossover distances are around 40 km in the oceanic crust of the Alarcon basin, increase to about 60-75 km in the transition zone and reach a maximum of about 100km for the continental land instruments. The total width of oceanic crust created at the Alarcon Rise, as determined from reflection profiles and initial refraction processing is about 130 km, which agrees with the bathymetric data. The transition zone is characterized by normal faulting- synrift faulting created sedimentary basins, which were later modified by additional normal faulting. The rifted margin appears to be symmetric, with about 180 km of transition zone on either side. However the southern margin is complicated by the fossil Magdalena spreading ridge, which lies about 150 km southeast of the Alarcon rise. We will present MCS results and an initial velocity model across the Alarcon basin.

T31E-0886 0830h POSTER

Crustal structure and rift evolution across the Guaymas Basin, Gulf of California

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A crustal-scale, active-source seismic experiment was conducted in the Gulf of California in the fall of 2002. This experiment, funded through NSF MARGINS, aimed to image crustal structure across conjugate margins of major basins throughout the gulf to determine the modes of extension, the influence of sedimentation and magmatism on breakup, and other features leading to a better understanding of the rifting process. Here we present results from Guaymas Basin, including analyses of marine MCS data recorded using the R/V Maurice Ewing's 6-km streamer and wide-angle data recorded on 39 OPSIP OBSs and 19 PASSCAL RefTeks onshore. The Guaymas Basin is heavily sedimented, with 0.5 km of sediments at the rift axis thickening to as much as 2 km at the margins. These sediments have masked the rift structure of this basin, which had seemed to have begun a true drift phase later than the basins in the south. Analysis of the seismic data show, however, that rifting proceeded to completion rapidly, and most of the crust underlying the Guaymas Basin is new igneous crust. In contrast to the southern gulf, rifting and subsequent crustal construction in Guaymas has been "magmatic", with crustal thicknesses of 12 km near the margin and 8 km near the spreading center, suggesting an along-axis gradient in either mantle temperature or dynamic upwelling that has persisted since the onset of rifting. Ingeous crustal structure generally mimics oceanic crust, with a 2- to 4-km-thick 4-5 km/s upper layer (likely intercalated sediments and sills) overlying a plutonic layer. A striking feature of the crust here is the asymmetry about the rift axis in plutonic-layer velocities and gradients, with velocities to the west of 6.4-6.9 km/s and a 6.6-7.0 km/s velocity gradient to the east. This is mimicked in the upper crust, with an average velocity of 5.0 km/s in the west and 4.0 km/s in the east. The rift axis features a 2-km-high, down-to-the east, low-angle fault(?) bounding a depression in the plutonic crust beneath the rift axis, which itself is offset from the geometric center of the basin. A combination of a rift axis offset from the locus of mantle upwelling and asymmetric tectonics at the rift may lead to evolved melts being emplaced west of the spreading center and more residual melts to the east, possibly representing a previously unknown type of tectono-magmatic asymmetry.

T31E-0887 0830h POSTER

Contributions to the Elevation North America

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Continental elevations result from a combination of buoyancy (i.e. compositional and thermal) and geodynamic forces. Thermal isostasy can produce nearly three kilometers of relief between cold shield platforms and hot rift zones. However, changes in bulk density and crustal thickness can potentially produce relief greater than nine kilometers; whereas, geodynamic contributions to elevation are frequently no greater than a few meters to a few kilometers. Therefore, elevation resulting from buoyant forces must first be removed before assessing the magnitude of geodyamic contributions to elevation. The extensive geologic and geophysical data coverage of North America as well as diverse tectonic settings are ideal for determining the buoyancy contributions to elevation and examining a range of possible geodynamic processes affecting elevation. Compositional buoyancy is removed for each of 15 tectonic provinces by determining the average bulk density and crustal thickness. An adjusted elevation is computed by equating the density-thickness product of an observed region to a standard crustal section (e.g. 40 km thick crust with average density of 2830 kg/m^3). Mean province elevations are computed using the digital elevation model GTOPO30 with a spatial resolution of 1 km2. Crustal thickness is determined from seismic refraction models. Rock types are estimated from a combination of surface geology, drill cores, xenoliths, seismic refraction velocities, and tectonic history; densities are then estimated by correlating rock types to laboratory Vp-P-T-density investigations. Thermal buoyancy is removed by computing the difference between the integrated thermal structure of the province and a standard continental lithospheric geotherm (characteristic of surface heat flow 40 mW/m^2) to 250 km depth. Heat flow is drawn from a global data set and supplemented with more recent heat flow data. Anomalous heat flow at individual sites are examined for possible disturbances resulting from thermal conductivity and heat production variations. Using the continental heat flow and elevation relation derived from this study, it is possible to identify province outliers where the thermal state is anomalous (transient, disturbed, etc.), the elevation is anomalous (dynamically supported, anomalous mantle, etc.) or both. Discriminating between these sources of elevation provide insights into the geodynamics of North America.

T31E-0888 0830h POSTER

Seismic imaging of the continent-ocean transition in the southern Gulf of California

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We present seismic reflection images and a preliminary velocity model of the crust at the mouth of the Gulf of California. The Gulf of California is a unique place to study rifting because the transition from rifted continental margin to oceanic crust to conjugate rifted margin occurs within a fairly short distance, making segments easy to recognize. In the fall of 2002, multichannel seismic (MCS) data were collected along an 550 km northwest southeast trending transect from the southern tip of the Baja peninsula over the East Pacific Rise to mainland Mexico. In addition, thirty-six ocean bottom seismometers (OBS) were deployed at 10 km spacing along the transect to collect wide-angle seismic data. Our goals are 1) to examine the relationships between extensional style, lithospheric composition, and rheology, and 2) to determine whether the Gulf of California margins are volcanic or non-volcanic. MCS images show oceanic crust that lacks seaward dipping reflectors or voluminous extrusives, indicating a non-volcanic rifted margin in the southernmost Gulf of California. Preliminary velocity models of the northwestern margin show an abrupt transition from a 25-km-thick continental crust to an oceanic crust of normal thickness.

T31F MCC: Level 2 Wednesday 0830h

Orogenesis, Metamorphism, and Exhumation I Posters *(joint with H, V)*

Presiding: **R N Pysklywec,** University of Toronto**; J Rahl,** Yale University

T31F-0889 0830h POSTER

Surface Heat Flow vs. Helium Isotopes in the Thermal Anomaly Areas of Tuscany (Italy)

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A wide part of Tuscany (North-Central Italy) is affected by a large heat flow anomaly: the highest values of heat flow correspond to the two geothermal fields of Larderello and Mt. Amiata, where values up to 1W/m^2 and 0.6 W/m^2 are reached, respectively. Several other thermal manifestations are scattered in the region. These geothermal fields are located in the inner Northern Apennines, affected by post-collisional extensional tectonics and widespread Late Miocene-Quaternary magmatism. The geothermal fields of Larderello and Mt. Amiata display considerable similarities from the geological-structural and thermal point of view, with some important difference. They differ with regard to fluids characteristics: the Larderello field is steam-dominated while the Mt. Amiata field is water-dominated. We compare the distribution at surface of ^{3}He/^{4}He ratio (R/Ra), a sensitive geochemical tracer of source, with heat flow and other geophysical and structural parameters like Bouguer anomaly and normal fault geometry, to improve knowledge on the two geothermal systems. To investigate the relationship among normal faults, geothermal fluids pathways, He surface distribution and heat flow, we constructed targeted geological sections through the geothermal areas of Tuscany. The geological sections were drawn down to the K-horizon (a regional seismic reflector discontinuously underlying the whole geothermal areas at a depth ranging between 3 and 7 km), integrating field data with borehole stratigraphies and reflection seismic surveys. Though slightly biased in space at surface, due to the normal fault geometry governing the fluids pathways, the highest R/Ra values show a good correspondence to the heat flow maxima. These results account for the role of the extensional shear zones as preferential ways of mantle-derived fluids uprise in the Larderello field. We stress the importance of mapping simple primary geophysical (temperature gradient, heat flow) and geochemical (He isotopic composition) data, compared with the structural geology, to define the principal fluid-flow paths in geothermal areas.

T31F-0890 0830h POSTER

Along-strike Variation in the Sandino Basin of Nicaragua and Implications for the Development of the Central American Forearc

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The Sandino forearc basin is about 40 km wide and filled with 6 to as much as 15 km of Upper Cretaceous to Recent sediments. The sediments overly the margin wedge, consisting of the Ophiolitic Nicoya complex of Cretaceous to Early Tertiary age. In the south, the basin thins rapidly southward against ultramafic rocks of the Santa Elena peninsula of Costa Rica. Sediment thickness locally exceeds 13 km in the central and northern parts of the basin. The oldest units (Upper Cretaceous-Middle Eocene) are very thick off northern Nicaragua, with relatively thin middle to late Cenozoic deposits. In contrast, off central Nicaragua the Middle-Upper Miocene units attain great thickness (5-6 km) and the older units are thin. This pattern suggests a history of successive deepening of the basin from north to south off Nicaragua. The Nicoya complex was emplaced during Late Cretaceous to Late Eocene. Coeval uplift of the outer high and subsidence of the forearc basin are recorded in the seismic data. The variation in sediment thickness suggests an early collision of an oceanic plateau or thickened basaltic ridge in this area and likely off El Salvador as well. Basin formation may have begun with early imbrication or underplating along its seaward edge in the north during the Eocene, continuing southward in the Upper Oligocene-Lower Miocene. During the Oligocene the Corvina and Argonaut anticlines divided the depocenter of the basin into an inner, deeper part, and a western, shallower part. The anticlines are structurally fault-propagation folds, although they may have a strike-slip component of displacement. Widespread normal faulting on the outer shelf and upper slope region in the late Cenozoic and stratigraphic evidence of subsidence of this region may coincide with a period of subduction erosion combined with a steepening subduction angle. Latest Miocene uplift of the sequences along the present coastal region shifted the basin depocenter westward. Slow uplift has continued along part of the central coast into the late Pleistocene.

T31F-0891 0830h POSTER

Lower Paleozoic Through Archean Detrital Zircon Ages From Metasedimentary Rocks of the Nome Group, Seward Peninsula, Alaska

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Metamorphic rocks of Seward Peninsula have been divided into two groups based on their metamorphic grade and history: The Nome Group and the Kigluaik Group. Although it is sometime been assumed that the higher structural position of the Nome Group versus the Kigluaik Group indicates the Kigluaik Group is older, this relationship and the age of the protoliths of these rocks has never been well-established. The Nome Group includes (delete the) lower grade blueschist and greenschist facies rocks which are widespread across the Seward Peninsula (delete) Rock types include pelitic schist, more mafic chlorite-white mica-albite schist, marble, quartzite, and metabasite. An early metamorphic event (pre-120 Ma) occurred at high pressure and relatively low temperature, and is everywhere overprinted by younger deformation and greenschist facies Rare eclogite facies assemblages are preserved in metabasites, and garnet-glaucophane in some of the pelitic schists. The Kigluaik Group includes upper greenschist to granulite facies rocks that are exposed in the core of a gneiss dome. They record a younger event (91 Ma) that occurred at higher temperatures and resulted in partial thermal overprinting of the Nome Group and upper greenschist to granulite facies assemblages forming in the Kigluaik Group. The Kigluaik Group and equivalent rocks in the Bendeleben and Darby Mountains represent at least in part similar protoliths to many of the units in the Nome Group (Till and Dumoulin, 1994). The boundary between the rocks of the Nome Group and those clearly affected by the second metamorphic event is placed arbitrarily at the "Biotite-in" isograd along the flanks of the gneiss dome. In order to assess the protolith ages and source rock ages for these units, detrital zircon ages were obtained from three samples from the Nome Group, with Kigluaik Group ages forthcoming. LA-MC-ICPMS U/Pb isotope analysis was used for dating. Two samples were collected from the western Kigluaik Mountains near Eldorado Creek and one further south along the Feather River. Each sample yielded 90-105 analyses and all uncertainties are 1 sigma. Chlorite schist MC-74 has a range of ages from the two youngest grains at 484 ± 18 Ma and 510 ± 7 Ma to 2984 ± 2 Ma. Chlorite schist LMC-30 has a youngest grain at 521 ± 2 Ma and an oldest grain of 2027 ± 12. Quartz-mica schist LMC-58 also has a youngest grain at 521 ± 2 Ma and an oldest grain of 2655 ± 7 Ma. All three therefore have lower Paleozoic zircons, suggesting Lower Cambrian or younger depositional ages. Combining the data from all three rocks results in peaks on a cumulative probability plot at (in descending order of importance): 600 Ma, 683 Ma, 1593 Ma, 522 Ma, and 2985 Ma, with several smaller peaks between 774-1540 Ma and 1685-1960 Ma. Published ages from Nome Group orthogneisses are 680 Ma, suggesting the samples so far analyzed are likely in part sourced from local basement rocks that were eroded to provide 680 Ma detrital zircons to sedimentary protoliths of part of the Nome Group.

T31F-0892 0830h POSTER

First Demonstration of Archean Accretionary Complex by Zircon Geochronology Instead of Index Microfossils

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The North Pole area (3.5 Ga) in the Pilbara Craton, Western Australia is one of the best regions in the Archean cratons to investigate accretion process at subduction zone, because this area had been subjected only to very low-grade metamorphism. A 1/5,000 scale mapping has been performed during the last 12 years in the North Pole area. The mapped area is divided into five units bounded by layer-parallel thrusts: Units-I, -II, -III, -IV and -V in ascending order. Greenstones in these units are divided into MORB-type (Unit-I and -II) and OIB-type (Unit-III, -IV and -V) units by oceanic plate stratigraphy (OPS) and geochemistry of the greenstones. The Unit-I and -II, the best exposed, are composed of 19 and 22 tectonic slices with similar lithostratigraphy, bounded by layer-parallel thrusts. Duplex structures are developed at cm- to mappable scale in these units. The duplex structure and OPS indicates that the North Pole area is an Archean accretionary complex. The sense of shear with horizontal shortening is top-to-the-east which indicates westward subduction. The reconstructed lithostratigraphy of each tectonic slice in MORB-type units reveals a simple pattern, from basaltic and pillowed greenstone, through bedded chert layer to mafic sedimentary rocks on the top, in ascending order in the same unit. This lithostratigraphy is quite similar to the Phanerozoic OPS, except for the mafic sedimentary rocks which suggest that the accretionary complex was formed in the intra-oceanic environment comparable to the present-day western Pacific Ocean. The five-fold pile nappe structure of granite-greenstone complex in the North Pole region indicates that the structural top is the oldest accreted unit, whereas the bottom is the youngest. This is opposite against the rift basin model proposed by previous workers. To confirm the geologic relations, we separated zircons from thin acidic tuff layers in bedded cherts. We used a laser ablation ICP-MS for zircon U-Pb dating combined with cathode luminescence image for checking igneous textures of zircons. The zircons from the Unit-III indicate age of 3463±34 and 3434±31 Ma, and from rhyolite in the Unit-IV, which is structurally near-top unit, show the oldest age of 3660±50 Ma in this area. We cannot obtain zircon age from lower two units (Unit-I and -II), but Pb-model age (3400 Ma) of galena has been reported from Unit-I (Richards et al., 1981). This age is consistent with age trend suggested by our zircon geochronology data. The granite intruding into these units indicates the youngest age of 3393±45 Ma. Granite age is consistent with lower intersect age of rhyolite from the Unit-IV. Thus, the younging trend of Unit from top-sitting Unit-IV to Unit-I is present, indicating that the North Pole area has grown toward structurally downward with time, as expected by field occurrence. This is the first demonstration that Archean greenstone belt is composed of accretionary complex. The break-through of the Phanerozoic accretionary complex in Japan has come from radiolarian geochronology, combined with OPS and detailed field mapping.

T31F-0893 0830h POSTER

2D Seismic Velocity Modelling in the Southeastern Romanian Carpathians and its Foreland (Vrancea Zone and Focsani Basin)

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The DACIA-PLAN (Danube and Carpathian Integrated Action on Processes in the Lithosphere and Neotectonics) deep seismic reflection survey was performed in August-September 2001, with the objective of obtaining of new information on the deep structure of the external Carpathians nappes and the architecture of Tertiary/Quaternary basins developed within and adjacent to the seismically-active Vrancea Zone, including the rapidly subsiding Focsani Basin. The DACIA-PLAN profile is about 140 km long, having a roughly NW-SE direction, from near the southeast Transylvanian Basin, across the mountainous southeastern Carpathians and their foreland to near the Danube Dalta. A high resolution 2D velocity model of the upper crust along the seismic profile has been determined from a first-arrival tomographic inversion of the DACIA-PLAN data. The shallowing of Palaeozoic-Mesozoic basement, and related structural heterogeneity within it, beneath the eastern flank of the Focsani Basin is clearly seen. Velocity heterogeneity within the Carpathian nappe belt is also evident and is indicative of internal structural complexity, including the presence of salt bodies and basement involvement in thrusting, thus favouring some current geological models over others. The presence of basement involvement implies the compressional reactivation of pre-existing basement normal faults. Members of the DACIA-PLAN/TomoSeis Working Group (see poster) should be considered as co-authors of this presentation.

T31F-0894 0830h POSTER

Basement blocks and basin inversion structures mapped using reprocessed Gulfrex 2D seismic data, Caribbean-South American oblique collisional zone

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We have reprocessed and reinterpreted more than 10,000 km of "Gulfrex" multi-channel 2D seismic reflection lines collected by Gulf Oil Corporation in 1972 along the northern margin of South America (offshore Venezuela and Trinidad). These digital data were donated to the University of Texas Institute for Geophysics and represent the largest single, digital reflection survey of the region. Reprocessing of these data included: format correction, filtering, post-stack multiple suppression, and fk migration. Reprocessed data were loaded and interpreted on a workstation. The data straddle a 2,000,000 km2 zone of Paleocene-Recent, time-transgressive, oblique collision between the Caribbean arc system and the passive continental margin of northern South America. Free-air, satellite gravity data shows the remarkable 1000-km-scale continuity of four basement ridges between the uncollided part of the Caribbean arc system (NS-trending Lesser Antilles arc) and the EW-trending collisional area north of Venezuela. The basement ridges involved in the Venezuelan collisional zone include: 1) Aruba-Bonaire-Curacao ridge that can be traced as a continuous feature to the Aves ridge remnant arc of the Lesser Antilles; 2) the partially inverted Blanquilla-Bonaire basin that can be traced into the Grenada back-arc basin; 3) Margarita-Los Testigos platform that can be traced to the Lesser Antilles volcanic arc; and 4) foreland basins and fold-thrust belts of eastern Venezuela (Serrania del Interior and Maturin basin) that can be

traced to the Tobago forearc basin and Barbados accretionary prism. Gulfrex data document the progressive change of basinal fault systems from NS-striking normal faults formed in extensional, Lesser Antilles intra-arc settings to rotated and inverted, NE and EW-striking normal faults deformed in the collisional area north of Venezuela. Age of initial shortening of basinal areas and inversion of normal faults setting does not follow the simple, expected pattern of west-to-east younging; instead important, regional pulses of regional shortening and normal fault inversion occurred during the Eocene and Middle Miocene. ESE-striking lateral ramp faults related to differential convergence across the region disrupt the lateral continuity of the arc-related basement ridges

T31F-0895 0830h POSTER

Postcollisional Deformation of the Alps: Results From Numerical Modeling

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In this work we present the results of a numerical modeling applied to study the large-scale deformation induced in the Alpine region by the Africa-Eurasia convergence during the postcollisional phase (last 40 Ma). We use the thin sheet approach which assumes a vertically averaged rheology and permits us to simulate the lithosphere as a thin viscous layer subjected to plane stresses. The coupled system of equations for momentum and energy conservation are numerically solved. We show the results of the evolution of stress and deformation fields in the Alpine region. Geological interpretations support the lower resistance of the orogenic region between the stiff European foreland and the Adriatic lithosphere. Each plate is modeled in terms of a rheologically different block and the Alpine deformation changes dynamically according to the local rheology, the velocity field and the assumed coupling between Adria and Eurasia. We also analyze how the changes of the relative velocity between the Adriatic and European plates during the last 40 Ma affect the present-day structure Alpine chain. We show that Adria-Europe convergence and gravitational collapse alone are not able to induce the observed lateral extrusion in the eastern Alps. Our results suggest that other effects, such relative variations of strength in the different zones, the change of kinematics regime of Adria and Europe during the last 40 Ma and east-west extension due to the retreat of the Carpathians subduction zone, must be taken into account.

T31F-0896 0830h POSTER

Orogenic Structures and Palaeozoic Basins Imaged by Potential Field Modelling

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Potential field data (gravimetric and magnetic) in the North Sea area is analysed with respect to identification of large scale lineaments, graben structures, intrusive complexes and Palaeozoic basins. Edges of magnetic sources are outlined by calculation of the horizontal gradient from the pseudogravity field and correlated with the observed gravity anomalies. There are clear differences between the Baltica, Laurentia and Eastern Avalonia plates in both the magnetic and the gravimetric data. The declination vector image of the gravity field indicates a significant, deep seated lineament just south of the Caledonian Deformation Front, coincident with the Elbe Line. It can be traced from Scotland across the North Sea and into northern Germany. Correlation with deep seismic normal incidence data (the MONA LISA profiles) shows that the lineament coincides with the termination in the lower crust of a band of crust cutting reflections, marking the transition into an area of high reflectivity. A 2D gravity and magnetic model of MONA LISA profile 3 shows evidence of over thrusting of Avalonia onto high density Baltica lower crust over a 150 km wide area. Lower Palaeozoic are found to exist along the entire profile with maximum thickness around 4 km. Near-vertical intrusions are modelled beneath the Central Graben and in the crystalline part of the Mid-North Sea - Ringkoebing Fyn High. By use of local Euler Deconvolution we have modelled depths to magnetic basement in the southern part of the North Sea. An average depth of 7.4 km is estimated for the Norwegian-Danish Basin and 8.0 km for the Horn Graben area. The depth calculations are constrained by power spectral density distributions which show similar results but also indicate the presence of magnetic Rotliegende deposits with depths between 3.0 and 4.2 km. By comparison with the top pre-Zechstein surface, we estimate the thickness of Palaeozoic deposits to be between 3 to 8 km in the Central Graben, 2 to 7 km in the Horn Graben and 3 to 6 km in the southern part of the Norwegian-Danish Basin.

T31F-0897 0830h POSTER

Mid-Cretaceous Exhumation of the Early Cretaceous Kamuikotan Blueschists in Hokkaido, Japan

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Unconformity and fluvial deposits containing blueschist clasts in a Cretaceous forearc basin sequence indicate that a part of the Kamuikotan high-P/T metabasites (Iwashimizu Complex: Valanginian-Barremian) was exhumed in the mid-Cretaceous (Aptian-Albian). The Iwashimizu Complex consists mainly of metabasites originated from subducted seamounts, accompanied by subordinate chert and turbidites. The complex is a pile of nappe units, each of which comprises a duplex of metabasite slices. Metamorphic grade decreases structurally downward from the blueschist facies to the lawsonite-albite facies. Metabasite clasts in the forearc basin were derived limitedly from the epidote-bearing upper unit, and they never contain lawsonite, the characteristic mineral in the lower unit. White-mica K-Ar ages of the structurally lowest units (Watanabe et al., 1994) are coeval to the unconformity event, suggesting that the exhumation of the upper unit and metamorphism of the lower unit contemporarily occurred. The most reasonable explanation may be that the structurally upper blueschist unit was rapidly jacked-up by subsequent underplating accretion of structurally lower unit during the seamounts subduction. Decrease of metamorphic grade structurally downward can be explained by the decrease of subducted slab dip, as suggested by younging of subducted oceanic crust based on fossil ages of oceanic sediments. The Iwashimizu Complex was originally overlain by the Jurassic Lower Sorachi Ophiolite, based on tectonostratigraphic comparison with the area where the blueschists were not exhumed in the mid-Cretaceous. The absence of detritus of the ophiolite origin suggests that the ophiolite must have been removed tectonically, not by sedimentary erosion, during the exhumation. The contrasting tectonism, i.e. structural thickening (duplex) and unroofing (presumable extension), can contemporarily occur during repetitive seamounts subduction, because of the forearc thickening in front of subducting seamounts, coupled with extensional failure in rear of them.

T31F-0898 0830h POSTER

Microstructural analysis of the ultrahigh-pressure Sulu terrane, eastern China

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We applied techniques of microstructural analysis to oriented samples from eclogites and host gneisses of the Sulu UHP terrane of eastern China to understand the exhumation process. Our field observations of top-to-the-(W)NW sense of shear in exhumation related fabrics are corroborated by microstructural kinematic indicators such as C'-type shear band cleavage, mica fish, sigma clasts, and quartz fabrics. The top-to-the-(W)NW sense of shear is recorded through the continuum of retrograde metamorphism from eclogite-facies conditions. Microboudinage of amphibole and zoisite parallels the stretching lineation and strain shadows with recrystallized quartz occur around porphyroclasts. Eclogite bodies displaying mesoscopic deformation fabrics are commonly dominated by symplectite textures at microscopic scale, suggesting static recrystallization occurred after deformation was partitioned into surrounding host gneisses as exhumation progressed. Syntectonic albite porphyroblasts from retrograde mafic schists interlayered with host gneisses contain hornblende and rutile-rich inclusion suites. This internal foliation is continuous with the external foliation defined by biotite. Locally, recovery of quartz and feldspar in host gneisses indicate that temperature outlasted deformation. Upper greenschist-facies mylonitic fabrics are preserved in the NW limb of a large SW-NE trending antiform near the Yantai-Qingdao-Wulian detachment zone. These data support a single stage of exhumation of the UHP unit from mantle to upper mid-crustal depths. U-Pb SHRIMP dating and 40Ar/39Ar thermochronology will reveal the ages of ultrahigh-pressure metamorphism and constrain the timing of cooling and deformation associated with exhumation.

T31F-0899 0830h POSTER

Reorganization of Strain in Response to Erosional Forcing at Intermediate Scales: Puli Embayment, Western Taiwan

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The Taiwan orogeny accommodates 82 mm of oblique convergence per year between the Philippine Sea and Eurasian plates and is situated in a region of very high rainfall, resulting in high rates of rock uplift and erosion. Studies in western Taiwan suggest that there is considerable along strike variation in late Quaternary erosion rates and in the modern distribution of strain along the western margin of the orogen. In the Puli Embayment, a 50 km wide, 1500 m deep depression within the Foothills belt, Hsueshan Range and Backbone Ranges of western Taiwan, lower elevation and enhanced exhumation are associated with a broad 50 km wide belt of active shortening hindward of the leading edge of the orogen. Localized high erosion rates have been shown to significantly influence the mechanical behavior of collisional mountain belts on timescales of 1-5 Ma where the wavelength of the erosional signal is on the order of the thickness of the brittle crust. Examples include the Southern Alps of New Zealand and the indentor corners, Nanga Parbat and Namche Bawa, of the Himalaya, where the geometry of the erosional signal is reflected in the topographic and petrological signal of the resultant mountain belt. The coincidence of enhanced exhumation, lower elevation and active deformation suggests that the Puli embayment is accommodating shortening and rock uplift in response to the reduction in mass. If so, it is occurring on shorter temporal and spatial scales than previously documented and may represent the early stages of river-induced thermal thinning leading to the formation of a structure on the scale of an anticlinorium. Western Taiwan provides an ideal setting in which to explore, on a suborogen scale, the implications of enhanced exhumation for the beginnings of reorganization of strain within an orogen at higher spatial and temporal frequency.

T31F-0900 0830h POSTER

Silicification of pelitic schist in the Iwakuni-Yanai area of the Ryoke belt, southwest Japan: Origin of competent layers in the deep crust

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Bright-layer reflections have been imaged at about 15-20 km depth in fore-arc region of southwest Japan, and most of the epicenter distributes above the bright-layer (Ito, 1999). To understand the cause of a seismic bright-layer with the mechanism of large inland

earthquake, we studied the low-P/T metamorphic rocks in the Ryoke belt, southwest Japan. The Ryoke belt in the Iwakuni-Yanai area is underlain by Jurassic accretionary complex and their metamorphosed equivalents. They were intruded by Cretaceous granitic rocks. Five metamorphic zones can be difined by mineral assemblages of pelitic rocks as a regional metamorphism before the intrusion; chlorite, chlorite-biotite, biotite, cordierite and sillimanite zones from north to south (Ikeda, 1993). Silicified rocks have been found in pelitic schist of the biotite zone and northernmost part of the cordierite zone. The pelitic schist is dark in color but silicification turned it to be pale gray or milky white. Silicified pelitic schist is mainly composed of fine-grained quartz and minor muscovite and biotite. The silicified pelitic schist forms layers or lenticular bodies several to fifty meters in thickness. The boundary between silicified rock layer and underlying pelitic schist is fairly distinct but that between the overlying pelitic schist is gradual. Quartz veins crossing high angles with schistosity were preferentially developed in the silicified rock layers, while schistosity-parallel quartz veins, which underwent plastic flow, were observed in the pelitic schist. En echelon quartz vein and fishnet-like quartz veins are characteristic of silicified rock layers. This mode of occurrence of quartz veins indicates competence of silicified rock layers relative to pelitic schist. Rock boundary with high competence contrast is probably a good reflector of seismic waves. Bright-layer reflections would arise from silicified rock layers if those are distributed in the deep crust to a considerable extent.

T31F-0901 0830h POSTER

Revising the Triassic Unroofing History of the Qinling-Dabie Collisional Orogenic Belt: New Detrital Zircon Provenance Data from the Songpan-Ganzi Complex Turbidites, West-Central China

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Approximately 300 new U-Pb SHRIMP ages were obtained from detrital zircons recovered from six samples of the Songpan-Ganzi Complex (SGC), a succession of turbidites over 10 km thick covering an area of 220,000 km2 in the Sichuan province of west-central China. Situated 2000 km along structural strike of the Late Triassic-Late Jurassic Qinling-Dabie orogen, a collisional belt produced by the suturing of the North China block (NCB) with the South China block (SCB), the SGC exists as the prime, yet unproven, candidate for the ultimate sink of Qinling-Dabie derived detritus. Age spectra recorded by two samples from the northeastern zone and two samples from the central zones of the SGC record an initial source of early Paleozoic rocks of the SCB during the late Middle Triassic/early Late Triassic; by the late Late Triassic zircon age spectra are dominated by a 1900 Ma population derived from the NCB. This data represents the most statistically robust zircon provenance data set and contradicts a previous interpretation of another data set of less than 50 U-Pb ages of detrital zircon crystals recovered from two Middle Triassic samples and one Upper Triassic sample of the central zone of the SGC that were interpreted to indicate a provenance shift from the mid-Proterozoic rocks of the NCB to a dominantly 750-850 Ma source derived from rocks of the SCB. Age spectra from samples collected from the western zone of the SGC indicate a dominantly Proterozoic source with no Triassic grains, which is inconsistent with the previous interpretation that the western SGC turbidites were sourced by a contemporaneous volcanic arc. Geobarometric data indicate that ultrahigh pressure metamorphic rocks exposed within the Qinling-Dabie orogen were at or near the surface by 200-230 Ma; however, the SGC as a whole does not contain a large population of Late Triassic zircons that would indicate a Qinling-Dabie orogen source. Instead, the abundant Early and Late Proterozoic grains suggest the SGC records erosion of the SCB, perhaps prior to collision of the SCB with the NCB, followed by unroofing of more than 100 km of NCB crust to expose the Qinling-Dabie UHP rocks as suturing of the NCB and SCB progressed.

T31G MCC: 3005 Wednesday 1020h

Heat Sources in the Core *(joint with GP, V, MR, DI)*

Presiding: **G Steinle-Neumann,** Bayerisches Geoinstitut, University Bayreuth**; B Buffett,** University of Chicago

T31G-01 1020h INVITED

Radiogenic Heat Production in the Core?

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Radiogenic heat production in the Earth is dominated by three elements: K, Th and U, which mainly reside in the Earth's mantle and crust. The global budget is determined from the fact that Th and U are both refractory. Thus, it is believed that the Th/U ratio of the bulk Earth must be identical to those of chondritic meteorites. In contrast, K is a volatile element, but like Th and U is lithophile and incompatible. Relative to CI chondrites (K/U about 70,000), K is depleted by a factor of 6-7 in the Bulk Silicate Earth (BSE) due to volatility. New determinations of the chondritic Th/U ratio provide a value of 3.6, which may be taken to represent the bulk Earth Th/U ratio. The Th/U ratio (BSE) of 4.2-4.3 is determined by regression from lead isotope systematics. The discrepancy between the inferred bulk Earth and BSE Th/U ratios can be taken to imply that U is partially siderophile in the Earth, an observation that requires that D(U)= 0.3 between metal and silicate. The implied amount of U present in the core is sufficient to provide about 2-3 TW of power for the geodynamo. The presence of a uranogenic heat source significantly affects geophysical estimates of the timing of inner core crystallization. Recent Os isotope data imply that several plume sources have interacted with the outer core at the CMB. If this is correct, the high Pt/Os ratio inferred for the outer core would be most efficacious at explaining the observed Os isotope ratios if the inner core crystallized prior to 3.5 Ga. Such an early age of the inner core is not possible if heat loss at the CMB is dominated exclusively by latent heat release, but requires an additional source of radiogenic heating. It should be noted that most highly siderophile elements are siderophile at 1 atm conditions. However, many lithophile elements (V, Cr, Mn) become more siderophile at higher P and T. The mineral constituents of iron meteorites are notably lacking in U and Th, requiring that if U is present in the Earth's core it must change its metal-silicate partitioning at high P-T. While U is a prospective heat source for the Earth's core, resolution of the issue will require high P-T partitioning data for U and Th. Geophysical treatment of the crystallization rate of the inner core should include a discussion of the effect of radiogenic contribution to core heat production from U.

T31G-02 1040h INVITED

A Radioactive Heat Source in Planetary Cores: Experimental Evidence for Potassium

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The idea and the extent to which potassium is a radioactive heat source in the Earth's core has been highly controversial for the past thirty years because of ambiguous and contradictory experimental results, presumably due to unsuspected experimental difficulties. We present here results of studies free of such difficulties to show conclusively that K is soluble in Fe-S melts. In synthetic systems composed of K-silicate, Fe-metal, and FeS, potassium is readily enters the Fe-S melt at 2 GPa and magmatic temperatures, at fO_2 1.5 log units below the iron-wustite (IW) buffer. The data show a precise loglinear relationship between the partition coefficient D_K (concentration of K in sulfide/concentration of K in silicate) and inverse temperature, indicating that the solubility of K in the sulfide melt shows a strong positive correlation with temperature (T). If the Earth's core formed by segregation of metallic liquids in the Fe-FeS system, these observations suggests the presence of a significant amount of potassium in the core with consequent radiogenic heat production. The effects of pressure and composition on the partitioning of K in to Fe-S melt are not well constrained at this time. Our preliminary data show no effect of pressure in the limited range of our experiments but a significant effect of silicate melt composition. Until the effects of these parameters are defined better, only a heuristic estimate of the core radiogenic heat production is possible. For a range of 3000-4000 K core mantle equilibration temperature, the K content of the core is 60-130 ppm with a present-day heat production at $0.4 - 0.8 \times 10^{12}$ Watts and exponentially more in the past. A similar analysis suggests the radioactive heat production in Mars core to be 3×10^{10} Watts. This additional heat source in the cores of Earth and Mars has major implications for a number of global processes and the early history of these planets. Among these are, the early but now extinct global magnetic field of Mars, the longevity of 3.5 b.y. old terrestrial magnetic field, the age of the Earth's inner core, and the internal dynamics of the solid planet.

T31G-03 1100h INVITED

Quantum theory and high-pressure experiments on iron-potassium alloying: Radioactivity in the Earth's Core?

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Ab-initio quantum mechanical calculations support experimental evidence that several percent potassium (K) can be alloyed into iron (Fe) at high pressure, suggesting that K may have been incorporated into the iron-rich core during and after core segregation. This alloying process is of great importance to the thermal state and history of Earth's deep interior as radioactive decay of ^{40}K could be an important source of energy for the geodynamo and mantle dynamics. To test the possibility of K subsitution into an ϵ-Fe unit cell, we performed density-functional based ab-initio calculations, with the projector augmented wave method as implemented in the Vienna ab-initio simulation package (VASP), of Fe supercells of various sizes in which K is substituted. In agreement with previous high-pressure diamond-anvil cell experiments we find that substitutional incorporation of K into ϵ-Fe causes the hexagonal close pack (hcp) structure to expand by an amount depending nonlinearly on pressure and concentration, with 3 atomic% substitution causing about 2% volume expansion at 35 GPa. We have used these results to analyze the amount of K that is alloyed into hcp ϵ-Fe found in experiments. Overall, these findings show that it is possible to sequester more than 0.1 atomic% (700 ppm by weight) of K into the Fe-based alloy of the Earth's core, which would provide upwards of 4.5 TW across the core-mantle boundary.

T31G-04 1120h INVITED

Thermal and Magnetic Evolution of the Earth's Core

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The magnetic field of the Earth is generated by convection in the liquid core and energy necessary for this process comes from the cooling of the core which provide several buoyancy sources. The thermodynamics of this system is used to relate the ohmic dissipation in the core to all energy sources and to model the thermal evolution of the core. If the same dissipation is maintained just before the onset of inner core crystallization, and the associated compositional convection, as at present, a much larger heat flow at the core mantle boundary (CMB) is necessary which, if extrapolated backward, may require a very high initial temperature. Two solutions to that problem are studied: either the ohmic dissipation was smaller then, which could be maintained with the same heat flow as at present or an important radioactivity is present in the core. The presence of radioactivity in the core makes the inner core only a few hundred million years (Ma)