The Canadian crustal stress database: Update to 2008

John Adams[1], J.F. Cassidy[2], G.C. Rogers[2], J. Ristau[2], A. L. Bent[1], and R.E. Baldwin[2]
1. Canadian Hazard Information Service, Geological Survey of Canada, Ottawa, Canada. jadams@nrcan.gc.ca
2. Pacific Geosciences Centre, Geological Survey of Canada, Sidney, Canada

ABSTRACT

The Canadian Crustal Stress Database, originally compiled in 1985 and subsequently updated in 1987 and 1994, has been updated as of January 1, 2008. Here we describe the updated database. The 1994 database consisted of 1828 entries that spanned the depth range from near-surface to more than 30 km. These entries include stress measurements based on earthquake focal mechanisms (0-50 km depth), oil well breakouts (1-5 km), hydraulic fracturing (0-5 km), overcoring for engineering works (0-200 m), overcoring in mines (>200 m), and other surface geological phenomena (buckles, folds, pop-ups, etc), and some geodetic (strain) measurements as aliases for stress. In 2008, a significant update - more than 740 new entries - was made. Approximately 90% of these new stress measurements are from western Canada with the remainder from eastern and northern Canadian earthquakes. They represent stress estimates from 548 regional moment tensor focal mechanisms, 16 Harvard moment tensor solutions, 172 P-nodal solutions, and 10 estimates from crustal shear-wave splitting. This updated database contributes to our understanding of the earthquake-generating crustal stress field in Canada and the cause(s) of stresses applied to the North American plate.

Key words: crustal stress, maps, earthquake focal mechanisms

PRESENTER'S BIOGRAPHY

John Adams has nearly 30 years experience in seismicity, seismotectonics and seismic hazards in Canada. He is responsible for the Canadian national seismic hazard maps and participates in writing standards relating to seismic-resistant design.

Spherical Harmonic Representation of Global Mantle Heat Flow

Cardoso[1] R. R., Hamza[1] V.M.
1. Observatório Nacional, Rio de Janeiro, Brazil, chalex@on.br

ABSTRACT

We report here progress obtained in compiling radiogenic heat production data sets for the Earth´s crust and its use for determining residual heat flux from the mantle. In the procedure adopted, the surface area of the Earth is divided into a regular grid system of 5^0 x 5^0 elements and data from global reference crust models employed for determining mean crustal thickness values. Following this, representative values of mean crustal radiogenic heat production values are calculated. The calculations are based mainly on heat production data available in previous compilations, but also take into consideration information on the type of crust (continental or oceanic) present in each of the grid elements. The data sets include not only values derived from results of direct measurements of the abundances of heat producing elements (U, Th and K) in samples but also estimates based on empirical seismic velocity – heat production relations. In addition, extensive use was made of the linear relations between surface heat flow and heat production in obtaining estimates for grid elements for which experimental data are not available. The results obtained indicate that the radiogenic component of heat flux in continental regions have a mean value of 21mW/m^2. Subcrustal heat flow values were calculated by subtracting the radiogenic contribution from the surface heat flow. The results obtained are employed in spherical harmonic analysis of mantle heat flow. In the present work, the harmonic analysis is extended to degree 36, which is compatible with the grid size of the reference crustal models and the results of recent higher degree harmonic representations of surface heat flow. Power spectral analysis of the sets of harmonic coefficients indicates that the global mean mantle heat flow is 56mW/m^2, which is substantially lower than the estimates reported in some of the recent studies. There are indications of a weak secondary peak in the power spectrum, between degrees 4 and 5 of the harmonic expansion. This is probably related to the sharp contrasts in heat production rates between continental and oceanic segments of the crust, whose lateral dimensions are comparable to the degree of resolution in harmonic analysis. As expected, most of the mantle heat flux occurs in regions of young ocean crust, with ages less than 55Ma. In continental regions mantle heat flow is substantially lower, with values of less than 25mW/m^2. The results also indicate that the component of global heat loss, arising from the internal thermal energy of the earth, is less than 20TW.

Key words: Spherical Harmonics, Mantle Heat flow

PRESENTER'S BIOGRAPHY

Graduated in Electrical Engineering, obtained M.Sc. and Ph.D. in Geophysics from the National Observatory in Brazil. Author of more than ten publications in Engineering and Geophysics. Currently Assistant Professor at Angra dos Reis College and Research Fellow of the Department of Geophysics, National Observatory, Rio de Janeiro, Brazil.

Evidence for small-scale thermal convection near the CMB from joint multi-scale analysis of seismic imaging and finite element modelling

M.V. de Hoop[1], R.D. van der Hilst[2], A.P. van den Berg[3], P. Wang[4], X. Shang[5], D.A. Yuen[6]

1. Purdue University, USA, mdehoop@purdue.edu
2. MIT, USA, hilst@mit.edu
3. Utrecht University, the Netherlands, berg@geo.uu.nl
4. MIT, USA, wangp@alum.mit.edu
5. MIT, USA, xfshang@mit.edu
6. University of Minnesota, USA, daveyuen@gmail.com

ABSTRACT

The discovery of the post-perovskite phase near the CMB has stirred a debate about the relative effects of thermo-chemical changes and distortion of the phase boundary by thermal convection. Previous work on chemical buoyancy in the D'' layer considered relatively long wavelength solutions with horizontal wavelengths greater than 600 km. We consider horizontal (vertical) wavelengths as short as 10 km (4 km) to determine if thermal convection with a post-perovskite transition is compatible with expanding multi-scale seismic imaging with ScS and SKKS precursors and coda of the core-mantle boundary region, or if composition must be considered.

We investigate the interaction of subducting lithospheric slabs with the D'' region, accounting for the post-perovskite phase transition, by numerical simulation with a cylindrical finite element convection model. Phase-dependent composite non-linear rheology is used with a greater propensity for non-linear creep in ppv regions. Our results confirm the formation of ppv lens-like structures of ~250 km thickness and > 1000 km lateral extent near remnants of cold downwellings; mantle regions where hot plumes emerge from the CMB are pv-rich. The cold ppv regions deform according to non-Newtionian flow and have lower viscosity than the hotter pv plumes, which have linear (Newtonian) rheology. In the numerical models, the base of the ppv lenses is inside the thermal boundary layer near the CMB and is marked by a stronger S velocity gradient than the top.

The evidence is built by subjecting the finite element modelling - upon subtracting the tomographic S-wavespeed background model used in the inverse scattering - to a decomposition into wave packets, restricted to (about 6) scales and orientations proven to be resolvable by the multi-scale imaging of large sets of global network data. This resolution is derived from a matrix representation of the generalized Radon transform, making use of the concentration of wave packets. We also analyze the ScS and SKKS images, in particular, possible multiple crossings of the phase transition with a wave packet decomposition, which opens new ways for joint seismic and geodynamic analysis of the D'' region.

Key words: seismology, geodynamics, Earth's deep interior.

PRESENTER'S BIOGRAPHY

De Hoop is professor at, and the director of, the Center for Computational and Applied Mathematics at Purdue University and founder and director of the Geo-Mathematical Imaging Group. He holds a (parttime) visiting professorship in the Department of Earth, Atmospheric and Planetary Sciences at MIT. He also holds a visiting professorship at the Graduate University of the Chinese Academy of Sciences (Beijing). He is a fellow of the Institute of Physics. He is the recipient of the 1996 J. Clarence Karcher Award of the Society of Exploration Geophysicists. He was a program leader and the chair of the Program on Random Media at SAMSI (the Statistical and Applied Mathematical Sciences Institute) in 2007-08. He is a member of the scientific committee of the Geomathematics Programme at PIMS (Pacific Institute for the Mathematical Sciences).

Styles of Lithospheric Scale Deformation in Mega-thrust Subduction Zones

Kevin P Furlong[1], Thorne Lay[2], Charles J. Ammon[1]

1 Dept. Geosciences, Penn State University,University Park, PA, USA
(kevin@geodyn.psu.edu), (cammon@geosc.psu.edu)
2. Department of Earth and Planetary Sciences, University of California, Santa Cruz, California, USA
(thorne@pmc.ucsc.edu)

ABSTRACT

Although the general plate tectonic model of subduction zone deformation and its relationship to the earthquake cycle for mega-thrust earthquakes is well known, there is neither consistency in such descriptions nor compatibility among seismological, geodetic, and geologic frameworks for such events. In particular in most seismologic studies of mega-thrust earthquakes there is an implicit assumption that the co-seismic slip is essentially symmetric across the fault surface – that is both the upper and lower plates moved equal amounts (but in opposite directions) during the rupture. Implicit in many geologic studies along convergent margins is the assumption that most permanent deformation is within the upper plate and the subducting slab basically transits the seismogenic zone with little permanent deformation. Two subduction zone locales, the Kurile and Solomon Islands, that have hosted recent Mw 8+ earthquakes demonstrate two end-member styles of subduction zone processes neither fully consistent with the conventional view. The November 2006 (thrust) and January 2007 (normal) earthquake pair in the Kuriles provide an opportunity to quantify the deformation within the subducting Pacific slab during the interseismic period. Based on the correspondence in slip during these events, we are able to both estimate the deformation (dominantly in the subducting slab and not in the overriding plate) and place a constraint on the static frictional strength of the megathrust interface of approximately 2-5 MPa. The 2007 Solomon Island Mw 8+ earthquake shows a distinctly different pattern of interseismic deformation. During this event, the propagating rupture traversed an active transform plate boundary between the separately subducting Australia and Solomon Sea plates. We interpret this to represent a situation in which interseismic deformation is primarily in the upper (Pacific) plate allowing the rupture to jump the fundamental barrier of a plate boundary. This is also compatible with limited GPS data available for the Australia plate near the trench indicating unimpeded subduction of Australia and thus little internal deformation of the subducting slab. These two subduction regimes indicate that there is likely a full continuum in how deformation is accommodated during subduction, and implies that attempts to determine the megathrust (and associated tsunami) potential of subduction zones using observations of upper-plate deformation is problematic.

Key words: Lithospheric processes, plate tectonics, subduction, megathrust earthquakes

PRESENTER'S BIOGRAPHY

Kevin Furlong is professor of geosciences at Penn State University. His research focuses on plate boundary processes, and in particular the lithospheric scale processes that lead to the formation of new plate boundaries and their evolution.

NOANET: the new permanent GPS network for Geodynamics in Greece

A. Ganas, **G. Drakatos**, S. Rontogianni, C. Tsimi, M. Papanikolaou and P. Argyrakis

Geodynamics Institute, National Observatory of Athens, 118 10 Lofos Nymfon, PO Box 20048, Athens, Greece. (g.drakat@gein.noa.gr / Fax: +30-210-3490180)

ABSTRACT

Greece is one of the most tectonically active regions of Earth. The country is located on a convergent plate boundary comprising the subduction of the African Plate under the Eurasian plate, while the Arabian plate approaches the Eurasian plate in a northwestward motion. The highest seismic activity in Europe currently occurs in the region of the western part of the subduction zone that includes the Ionian Islands. NOA has begun installing permanent GPS stations on February 2006 including a EUREF permanent station in Attica, NOA1. Currently we operate ten (10) continuous GPS stations around Greece all sampling at 1-s and transmitting real-time data to Athens. 30-s data can be downloaded from: http://194.177.194.200/gps.html . All stations are equipped with Leica 1200 GRX Pro receivers and Leica AX1202 geodetic antennas. The 30-s data have been processed with GAMIT/GLOBK 10.3 scientific software. We included in our processing IGS and EUREF sites in order to get a more robust solution. The quality of the solution is still under evaluation; however the network has already produced valuable data for co-seismic deformation. One example is the displacement from a strong, shallow earthquake that occurred in NW Peloponnesus on 8 June 2008. We also present a first velocity map and daily and monthly time series used to evaluate the preliminary velocity field

Key words: GPS network, high-rate GPS, Greece

PRESENTER'S BIOGRAPHY

Dr George Drakatos received his BSc (1980) in Geology at the University of Athens, Greece, and his Post-Graduate Diploma (1987) in Seismology and Earthquake Engineering at the International Institute of Seismology and Earthquake Engineering (Tsukuba, Japan) and his PhD (1992) degree in seismology at the University of Athens, Greece. His research involves studies of crustal structure, applications of tomography, aftershock analysis, and risk management studies. Since 1984 he is employed at the Institute of Geodynamics of the National Observatory of Athens and since 2003 is employed as Research Director. He has been involved in several EU and national funded projects and he has more than 70 publications in scientific journals and international conference proceedings.

A Magma Accretion Model for the Formation of Oceanic Lithosphere and Implications for Hydrothermal Circulation in Stable Ocean Crust and Global Heat Loss

Hamza[1] V.M., Cardoso, R.R., Alexandrino[1] C.H.
1. Observatório Nacional, Rio de Janeiro, Brazil, hamza@on.br

ABSTRACT

A simple magma accretion model of the oceanic lithosphere is proposed and its implications for understanding the thermal field of oceanic lithosphere examined. The new model (designated VBA) assumes existence of lateral variations in accretion rates and temperatures at the base of the lithosphere, similar in character to those observed in magma solidification processes in the upper crust. However, unlike the previous thermal models of the lithosphere, the ratio of advection to conduction heat transfer (the Peclet number) is considered a space dependent variable. An approximate solution to this non-linear problem of variable basal heat input has been obtained by the method of integral transform. The results of numerical simulations reveal that the widely used McKenzie Plate model is a particular case of the more general class of VBA models, where the magma accretion rate is allowed to vary with distance from ridge axis. According to VBA models the thickness of the young lithosphere increases with distance from the ridge axis, at rates faster than those predicted by Half-Space Cooling and Plate models. Another noteworthy feature of the new model is its ability to account for the main observational features in the thermal behavior of both young and old oceanic lithosphere. Thus, heat flow and bathymetry variations calculated on the basis of the VBA model provide vastly improved fits to respective observational datasets. More importantly, the improved fits to bathymetry and heat flow have been achieved over the entire age range of oceanic lithosphere, and without the need to invoke the ad-hoc hypothesis of large-scale hydrothermal circulation in stable ocean crust. Also, use of VBA model does not lead to artificial discontinuities in the temperature field of the lithosphere, as is the case with GDH reference models. The results of the VBA models provide a better understanding of the global heat flow variations and estimates of global heat loss. In particular, the model is capable of reproducing regional-scale features in the thermal field of the oceanic crust, identified in recent higher degree spherical harmonic representations of global heat flow. The results suggest that estimates of global heat loss need to be downsized by at least 25%.

Key words: Magma Accretion Model, Oceanic Lithosphere, Hydrothermal Circulation, Global Heat Loss.

PRESENTER'S BIOGRAPHY

Graduated in Physics, M.Sc. Degree in Applied Physics (University of Kerala, India) and Ph.D. in Geophysics (University of Western Ontario, Canada). Author of over one hundred publications in Geophysics. Currently Head of the Geothermal Laboratory and Full Professor of the Department of Geophysics, National Observatory, Rio de Janeiro, Brazil.

Thermal Evolution of the Descending Lithosphere Beneath the Southeastern Carpathians

Alik Ismail-Zadeh[123], Gerald Schubert[4], Igor Tsepelev[5], Alex Korotkii[5]

1. Geophysikalisches Institut, Universität Karlsruhe, Hertzstr. 16, Karlsruhe 76187, GERMANY. E-mail: Alik.Ismail-Zadeh@gpi.uka.de
2. Institut de Physique du Globe de Paris, Pl. Jussieu 4, Paris 75005, FRANCE
3. MITPAN, Russian Academy of Sciences, Profsoyuznaya str. 84/32, Moscow 117997, RUSSIA
4. Department of Earth and Space Sciences & Institute of Geophysics and Planetary Physics, University of California, 3806 Geology, 595 Charles Young Drive East, Los Angeles, CA 90095-1567, USA
5. Institute of Mathematics and Mechanics, Ural Branch, Russian Academy of Sciences, S. Kovalevskoy ul. 16, Yekaterinburg 620219, RUSSIA

ABSTRACT

Mantle heterogeneities imaged by seismic tomography in the SE-Carpathians contain information on the present thermal state of the mantle. Based on *P*-wave seismic velocity anomalies we develop a model of the present mantle temperature beneath the region and combine the model with a model of crustal temperature constrained by heat flow data. The modeled temperatures are assimilated into the geological past using the information on the regional movement in the Early and Middle Miocene. Prominent thermal states of the lithospheric slab descending in the region are restored from its diffuse present state. In Miocene times the slab geometry clearly shows two portions of the sinking body. The northwest-southeast oriented portion of the body is located in the vicinity of the boundary between the East European and Scythian platforms, and this portion of the sinking body may be a relic of cold lithosphere that has traveled eastward. Another portion has a northeast-southwest orientation and is related to the present descending slab. Above a depth of 60 km the slab had a concave thermal shape, confirming the curvature of the Carpathian arc, and a convex surface below that depth. The slab maintained its convex shape until it split into two parts at a depth of about 220 km. We propose that this change in the slab geometry, which is likely to be preserved until the present, can cause stress localization due to the slab bending and subsequent stress release resulting in large mantle earthquakes in the region. Also we hypothesize that either the processes of dehydration and partial melting of the descending lithospheric slab or dragging down of hotter rocks from the adjacent uppermost mantle by the slab are possible causes of the reduction in seismic velocities beneath the Transylvanian Basin.

Key words: mantle dynamics, Vrancea, lithospheric slab, subduction, data assimilation

PRESENTER'S BIOGRAPHY

Alik Ismail-Zadeh received his B.Sc. (1982) in mathematics from Baku State University, M.Sc. (1983) in mathematical physics from M. Lomonossov Moscow State University, Ph.D. (1989) and Sc.D. (1997), both in geophysics, from the Russian Academy of Sciences (RAS). He has been a research professor at RAS, Moscow (since 1998); senior research fellow at University of Karlsruhe (since 2001), and professor of IPG Paris (since 2005). His research experience covers numerical and analytical modeling, data interpretation and assimilation in studies of dynamics and structure of the lithosphere, and the mantle.

Seventy years of heat flow research in southern Africa

Michael Q W Jones

School of Geosciences, University of the Witwatersrand, South Africa, michael.jones@wits.ac za

ABSTRACT

The first modern heat flow measurements in continental areas were made by Sir Edward Bullard and published in his famous 1939 paper entitled "Heat Flow in South Africa". Since then several South African and overseas scientists have made important contributions to the collection of surface heat flow data in the southern African region and thermal modelling of the lithosphere. This paper reviews the southern African data base, which consists of more than 230 observations, including approximately 60 unpublished values. Although the distribution of observations is not as uniform as would be desired, there is sufficient information to show that the heat flow pattern matches the tectonic framework of the subcontinent. The most obvious correlation is the distinction between the low heat flow in essentially Archaean cratonic regions (particularly the Kaapvaal and Zimbabwe cratons) and the higher heat flow in the surrounding Proterozoic mobile belts (such as the Namaqua and Damara belts) and a rough increase in surface heat flow with decreasing tectonic age. The difference between these heat flow regimes can be attributed partly to the depth integrated radioactive heat production of the crust and partly to heat influx from the mantle. Shorter wavelength heat flow anomalies within tectonic provinces and close to their boundaries can be attributed to local variations in upper crustal radioactivity. The heat flow and heat production data together with thermobarometric data from kimberlite nodule studies provide important constraints on models of the temperature structure of the lithosphere below southern Africa. The results of modelling suggest a maximum lithospheric thickness of approximately 300 km below the Kaapvaal craton, with thinner lithosphere below the mobile belts. This is consistent with recent seismological observations in South Africa.

Key words: Heat flow, South Africa, lithosphere structure.

PRESENTER'S BIOGRAPHY

Dr Michael Jones is a lecturer in the School of Geosciences, University of the Witwatersrand, and coordinator of the geophysics teaching programme. He has been involved in geothermal research for more than 30 years. His research interests include applications of thermal geophysics to tectonic studies, present and past structure of the lithosphere, refrigeration of deep mines, past climatic change and geothermal energy.

Constraints on the structure and dynamics of Tien Shan from integrative modelling of gravity and seismic data

Mikhail K. Kaban

GeoForschungsZentrum Potsdam (GFZ), Germany, e-mail: kaban@gfz-potsdam.de
IPE RAS, Moscow, Russia

Tien Shan is the world largest and most active intracontinental mountain belt. The high level of historical and instrumental seismicity implies that crustal deformation in the Tien Shan is active at high rates. These mountain building processes result from the convergence between India and Eurasia, with the Tien Shan absorbing a significant part of the shortening. This situation is outstanding for intracontinental mountain belts. The lithospheric mechanism controlling the crustal shortening remains however unresolved. A striking disagreement exists between the shortening rates of ~20 mm/yr (from GPS measurements) and ~10 mm/yr (from seismic moments of large crustal earthquakes). Density heterogeneity of the lithosphere and upper mantle is one of the main factors controlling tectonic processes. In this study we integrate gravity data from the new satellite missions and ground observations and recently obtained results of seismic studies (Vinnik et al., 2004,2006) to model density structure of the crust and upper mantle and the style of the geodynamic processes responsible for high rate deformations in the region. The obtained results can be summarized in the following points: (1) We detect a very strong deflection of the Tien Shan lithosphere from isostatic equilibrium. The model of pure crustal shortening does not work in the studied area. The best fit of the modelling results is found for the model according to which the Tarim plate partially underthrusts Tien Shan; (2) It is necessary to assume partial detachment of the lithosphere if the present convergence rate was kept during all history of Tien Shan; (3) Large density-velocity anomalies in the upper mantle are found in the central part of the studied area. These anomalies could be a result of magmatic underplating during the initial stage of tectonic evolution; (4) The weak lithosphere, which is a result of magmatic intrusion, could be the factor that provoked growth of mountains after collision of India and Eurasia.

Keywords: Lithosphere, gravity model, Tien Shan

Presenter's Biography

Mikhail K. Kaban

Mikhail Kaban is currently employed as a senior scientist at GeoForschungsZentrum, Potsdam. The research topis are generally related to construction and evaluation of density models of the Earth's crust and upper mantle based on an integrative interpretation of gravity, seismic and geological data; and modelling of the global mantle density structure with construction of a snap-shot global dynamic model of the Earth mantle. M. Kaban has defended his PhD thesis entitled "Isostatic compensation of the Earth's crust structures"in 1987. In 2003 he has got a habilitation degree (Dr. of Scince) with the paper "Density inhomogeneities of the upper mantle, lithosphere isostasy and geodynamics". Before GFZ, M. Kaban has been working at the Institute of Physics of the Earth, Moscow and up to now he keeps a part time position at this Institution as a leading scientist.

Teleseismic shear wave splitting and lithospheric anisotropy beneath Iran

A. Kaviani[1], **D. Hatzfeld[2]**, A. Paul[2], M. Tatar[3], K. Priestley[4]

1. Institute for Advanced Studies in Basic Sciences, P.O. Box 45195-1159, Zanjan, Iran, ayoubkaviani@yahoo.com
2. Laboratoire de Géophysique Interne et Tectonophysique, Université Joseph Fourier and CNRS, P.O. Box 53, 38041 Grenoble, France. denis.hatzfeld@ujf-grenoble.fr, anne.paul@ujf-grenoble.fr
3. International Institute of Earthquake Engineering and Seismology, P.O. Box 19395-3913, Tehran, Iran, mtatar@iiees.ac.ir
4. Department of Earth Sciences, Bullard Labs, Madingley Road, Cambridge CB3 0EZ, U.K. keith@madingley.org

ABSTRACT

Records of core-refracted phases from permanent and temporary seismic stations are analysed to provide the first map of seismic anisotropy covering most tectonic provinces of Iran. Splitting parameters are very coherent at the scale of a single province, but they strongly differ from one province to its neighbours. No significant splitting is observed in the mountain ranges of Zagros, Alborz, and Kopeh Dagh. Anisotropy with average time lags of 1.1±0.3 s and fast axes oriented mostly NW-SE is observed in the microblock of Central Iran. This heterogeneous splitting pattern with changes over short length scales suggests that anisotropy originates in the lithospheric mantle. Moreover the directions of fast axes do not coincide with the absolute plate motion in the no-net rotation frame, suggesting that the observed splitting cannot be explained by a simple model of asthenospheric flow. The null measurements in the mountain belts may be related to widening-thinning in a subhorizontal deformation zone, or to horizontal shortening and thickening by pure shear as proposed from synthetic models of olivine fabric. For Central Iran, which accommodates a continental collision between Arabia and Eurasia, we favour the hypothesis of an anisotropy related to the maximum shear of the Lithosphere. Our data are therefore not coherent with previous models that explain shear-wave splitting in the neighbouring regions of Eastern Anatolia and Saudi Arabia by simple asthenospheric flow.

Key words: Iran, Anisotropy, Lithosphere, Geodynamics

PRESENTER’S BIOGRAPHY

Denis Hatzfeld is a French seismologist involved for the last decade in the study of the seismotectonics and of the seismological structure of the Eastern Mediterranea and Iran

Himalayan Tectonic Model and the Great Earthquakes

J. R. Kayal

School of Oceanographic Studies, Jadavpur University, Kolkata 700032, India
Email: jr_kayal@yahoo.com

The most accepted conceptual tectonic model of the Himalayan Seismic Belt (HSB) suggests that the earthquakes in the HSB, between the Main Boundary Thrust (MBT) and the Main Central Thrust (MCT), occur on the *Plane of Detachment* at a shallower depth (15-20 km). The plane of detachment is an interface that separates the Indian shield and the Himalayan sedimentary wedge; some authors named it Main Himalayan Thrust (MHT). Below the MCT lies the Basement Thrust Front (BTF), a 'ramp' on the plane of detachment. The ramp, a geometrical asperity, accumulates the stress due to the collision tectonics between the gentle dipping Indian plate and the overriding Tibetan plate. It was suggested that the past great earthquakes occurred on the plane of detachment. This model was suggested based on the teleseismic data. Aftershocks of the two recent strong earthquakes, the 1991 Uttarkashi (M 6.6) and the 1999 Chamoli (M 6.3) in western Himalaya, in the HSB that occurred to the north of MBT were well studied by temporary networks, and it was observed that the model fits fairly well with these two earthquake sequences.

The recent earthquake data of the local permanent and temporary networks and a re-examination into the source processes of the past great earthquakes in the Himalaya, however, do not support this model. The four known great (M~8.0-8.7) earthquakes in the Himalaya, from west to east, the 1905 Kangra, 1934 Bihar, 1897 Shillong and the 1950 Assam, possibly cannot be explained as shallow *plane of detachment* earthquakes. The recent local network data show that the source of the 1905 Kangra earthquake, that occurred to the south of MBT, is possibly deeper (30-40 km), much below the plane of detachment. A similar observation is also made for the 1934 Bihar earthquake that occurred to the south of MBT on the east Patna fault; the source was also deeper (~ 40 km). This deeper source is further evidenced by the recent well located 1988 earthquake (Ms 6.6) at a depth ~ 60 km near the epicenter of the 1934 earthquake. The 1897 event that occurred in the Shillong Plateau, about 150 km south of the MBT, is argued to have generated by *pop-up* tectonics of the Plateau; it is rather a shield earthquake, not a Himalayan earthquake. The 1950 earthquake, on the other hand, occurred in the Assam syntaxis zone by strike slip mechanism; it cannot be correlated with the typical Himalayan thrust earthquakes on the plane of detachment. We argue that the earthquakes to the north of MBT in the HSB in western Himalaya though fit fairly well with the conceptual tectonic model, the past four great earthquakes in the Himalayan front, that occurred to the south of the MBT, are not shallow *plane of detachment* earthquakes. Each great past earthquake in the Himalayan front occurred by complex tectonic processes in its own unique tectonic environment.

Key words: Plane of detachment, Himalayan seismic belt, great earthquakes, thrust, pop-up tectonics

JR Kayal

I did my M Sc (Appl Geophys) from the Indian School of Mines, Dhanbad, in 1969. After about 10 years of experience in geophysical exploration for oil & minerals, I did my Ph D in Microearthquake Seismology from the Victoria University of Wellington, New Zealand in 1983 as a Commonwealth Scholar. I rejoined the Geological Survey of India (GSI) in 1984, and continued my research in seismology & tectonics. Seismotectonics as well as seismic tomography of the Himalayan, Indo-Burma-Andaman-Sumatra and the Indian shield earthquake sources was studied by me for the last 25 years. I retired from the GSI on November 30, 2006 as Deputy Director General, Head of Geophysics. Since 2007, I am an Emeritus Scientist, fellowship awarded by the CSIR (Council of Scientific and Industrial Research, Govt of India), and Adjunct / Visiting Professor to various Universities in India and abroad.

I am author of more than 100 research papers in national and international journals, editor / reviewer of several Books and many international journals. I have presented more than 100 papers and invited lectures in India and abroad. I am author of a Book: ***Microearthquake Seismology and Seismotectonics of South Asia,*** published (April, 2008) by the Springer/Capital Pub.

I am a member of several scientific societies including Assoc. Expl. Geophys, MGMI, Am Geophys Union, UNESCO Committee on South Asia Seismic Analysis etc. I was honoured with a "**National Award**" by the Govt of India in 1994, and was Awarded "**Fellow**" by several Scientific Societies in India and abroad. I feel proud to be a member of the great geo-scientific community of the world.

Seismological Modeling of Localized P-wave and S-wave Reflectivity in D″

Thorne Lay

Earth and Planetary Sciences Department, University of California, Santa Cruz, USA 95064,
thorne@pmc.ucsc.edu

ABSTRACT

Seismological waveform stacking and migration investigations are revealing unprecedented levels of fine-scale structure in the deep mantle. While large-scale patterns of volumetric heterogeneity are well-imaged by travel time analyses and seismic tomography, waveform studies are essential to reveal the ‘rough’ structure associated with chemical and phases boundaries. Detailed P-wave and S-wave velocity structures for the lowermost mantle beneath the central, northern and eastern Pacific obtained by broadband waveform stacking and modeling procedures indicate distinctive characteristics of low- and high-velocity regions in the deep mantle, with multiple seismic reflectors occurring in both regions. The central Pacific region is located within the tomographically-resolved large low shear velocity province (LLSVP) beneath the Pacific that is variously interpreted as a relatively hot “superplume” or large, dense chemically distinct “pile”. The localized seismic reflectivity in this region includes rapidly varying depth of a simultaneous P-wave and S-wave velocity increase (D″ discontinuity), evidence for an S-wave velocity decrease within the D″ layer that may be paired with the shallower increase, and a thin (15-km) moderate strength ultra-low velocity zone (ULVZ) for both P- and S-waves right above the core-mantle boundary (CMB). Other investigators have found similar complexity within the African LLSVP. The eastern Pacific region is located within the circum-Pacific band of high shear velocity that is variously interpreted as a relatively cold “slab graveyard” and/or region with post-perovskite being present. The localized reflectivity in this regions includes anti-correlated bulk-sound velocity and S-wave velocity contrasts at the D″ discontinuity, small P- and S-wave velocity increases and changes in velocity gradient within the D″ layer, and an S-wave velocity decrease in the lowermost 50-75 km of the mantle that may be paired with the D″ discontinuity, but there is no resolvable ULVZ under the Cocos Plate or Mexico. Large-scale migrations support the presence of complexity. A weak ULVZ and very small D″ discontinuity is found under the northern Pacific. The feature identified as the D″ discontinuity has been attributed to the post-perovskite phase transition occurring in both regions, with regional differences in bulk chemistry and thermal structure being invoked to account for the observations. We consider whether predicted effects of Fe and Al variations on the perovskite-to-post-perovskite transition elasticity can be reconciled with the distinct high-resolution P- and S-wave reflectivity structure in each region, including the D″ discontinuity, the paired discontinuities that may involve reverse transformations back to perovskite, and the presence/absence of ULVZ. The change in velocity gradient detected under the east Pacific is a surprisingly well-defined P-wave feature, and may correspond to the upper edge of a thermal boundary layer, although there is evidence for small S-wave velocity increases at about the same depth, which might favor a phase or chemical boundary.

Key words: core-mantle boundary, post-perovskite phase transition, thermal boundary layer, lower mantle structure.

PRESENTER’S BIOGRAPHY

Thorne Lay is a seismologist, with interests in the rupture process of large earthquakes, seismic waves in three-dimensional media, nuclear explosion discrimination, and deep Earth structure and dynamics. He was founding Director of the Institute of Geophysics and Planetary Physics branch at the University of California, Santa Cruz where has held a professorship since 1990. He served as Chair of the Earth Sciences Department at UCSC from 1994-2000, Director of the Institute of Tectonics from 1990-1994, Director of IGPP-UCSC from 1999-2005, and is currently director of Center for the Study of Imaging and Dynamics of the Earth (CSIDE). He recently served as Chair of the Board of Directors of Incorporated Research Institutions for Seismology (IRIS). He is author or co-author of 337 research publications including 1 textbook, 1 monograph, 1 edited monograph, 225 publications in refereed books and professional journals, and 109 technical reports, book reviews, and conference proceedings.

Lithospheric gravitational instability beneath the Southeast Carpathians - geodynamical models

Piroska Lorinczi and **Gregory A. Houseman**

School of Earth and Environment, University of Leeds, Leeds, LS2 9JT, UK
P.Lorinczi@see.leeds.ac.uk, G.Houseman@see.leeds.ac.uk

ABSTRACT

The Carpathians mountain system of Central and Eastern Europe surrounds the extensional Pannonian and Transylvanian Basins. Their southeastern part of the Carpathians, known as the Vrancea region, is characterised by a narrow, localised (~30 km x 80 km in the horizontal plane) zone of strong seismic activity extending to 200 km depth. The seismicity is usually attributed to subduction of oceanic lithosphere, although subduction is assumed to have finished at about 11 Ma, and the seismicity remains strong now. We calculate the seismic strain-rate tensors for the period 1967-2007, and describe the variation of strain-rate with depth. The observed results are compared with strain-rates predicted by numerical experiments. We develop a new dynamical model for this region based on the idea of viscous flow of the lithospheric mantle permitting the development of local continental mantle downwelling beneath Vrancea, due to a Rayleigh-Taylor instability that has evolved since the cessation of subduction at 11 Ma. The model simulations use a Lagrangean frame 3D finite-element algorithm solving the equations of conservation of mass and momentum for a spatially varying viscous creeping flow. The finite deformation calculations of the gravitational instability of the continental lithosphere demonstrate that the Rayleigh-Taylor mechanism can explain the present distribution of deformation within the downwelling lithosphere, both in terms of stress localisation and amplitude of strain rates. The spatial extent of the high stress zone that corresponds to the seismically active zone is realistically represented when we assume that viscosity decreases by at least an order of magnitude across the lithosphere. The downwelling is part of a planform for gravitational instability that is inherently three dimensional and was triggered in these experiments by a harmonic perturbation in the form of a first order Bessel function (with m=1 asymmetry). The mantle downwelling is balanced by lithospheric thinning in an adjacent area which would correspond to the Transylvanian Basin. Crustal thickening is predicted above the mantle downwelling and minor thinning beneath the basin.

Keywords: Lithospheric Deformation, Gravitational Instability, Mantle Dynamics

PRESENTER'S BIOGRAPHY

Greg Houseman is a graduate of the University of Sydney, and gained his PhD at the University of Cambridge in 1982. He has worked at Harvard University, the Australian National University, and Monash University in Melbourne and, since 2001, is Professor of Geophysics in the School of Earth and Environment at the University of Leeds. His research interests revolve around the quantification of lithospheric-mantle interaction and the application of seismic tomography in revealing structure of lithosphere and upper mantle. He is currently a Vice-President of IASPEI.

GPS-Geodynamic Research in and Adjacent to Morocco

Taoufik Mourabit[1], Abdelilah Tahayt[1-4], Abdelali Fadil[2], Simon McClusky[3] and Robert Reilinger[3],

1- Abdelmalek Essaadi University, Tangier, MOROCCO
2- Mohamed V University, Rabat, Morocco
3- MIT, Cambridge, MA, USA,
4- Observatoire Midi-Pyrénées / UMR 5562, Toulouse, France

GPS-geodynamic observations were initiated in Morocco in 1999 with the establishment of a CGPS tracking station in Rabat that continues to provide daily observations to the IGS. Survey observations were subsequently undertaken on a 22-station network also in 1999. At present, our group maintains 4 CGPS stations and we continue to make periodic observations on 28 survey sites well distributed throughout the country (last observed in 2006). These GPS observations have provided a robust velocity field for NW Nubia that constrains Nubia plate motion (McClusky et al., 2003, GJI), internal deformation of the Nubian plate adjacent to the Nubia-Eurasia continental "collision" zone (Fadil et al., 2006, Geology, Tahayt et al., 2008, C.R. Geosciences), and the character and tectonic significance of the 2004 Al Hoceima earthquake (Tahayt et al., 2008a, Journal of teledetection). Results include a relatively slow rate of crustal shortening across the Atlas Mountain system (~ 0.7 ± 0.5 mm/yr) that is roughly consistent with geologic estimates (~ 1-2 mm/yr, Megraoui et al., 1998, EPSL), and anomalous southward motion of the central Rif Mountains in N Morocco with respect to stable Nubia at rates reaching 3-4 mm/yr. Anomalous motion of the Rif Mts. appears incompatible with crustal extrusion from the Nubia-Iberia collision zone or with westward rollback of a subducted plate beneath Gibraltar, but is consistent with N-S extension of the Alboran Sea that has characterized the oblique collision zone for the past 30 Ma. We suggest that southward motion of the Rif is due to sub-crustal processes, in particular, southward rollback and delamination of the subducted Nubian plate beneath the Rif Mts.

In this presentation we will describe the most recent tectonic results of our GPS studies and attempt to review other active GPS-geodynamic initiatives in Morocco to provide a basis for future coordination and collaboration.

Contact : Taoufik Mourabit ; tmourabit@gmail.com

Slichter mode (Inner Core Oscillations) detected by the Fourier Strain Analysis

Makoto Okubo[1]
Tono Research Institute of Earthquake Science (TRIES), Association for the development of Earthquake Prediction (ADEP), 1-63 Yamanouchi, Akeyo-cyo, Mizunami, Gifu, 509-6132 JAPAN, okubo@tries.jp

ABSTRACT

Slichter mode, which was predicted by Slichter (1961), is very long period translational oscillation of earth's inner core. This mode, which includes three eigenfrequencies (ω_{-1}, ω_0 and ω_1; ~0.05mHz), will be excited by great earthquake, such as the 1960 Chilean earthquake, and the 2004 Sumatra earthquake. Because these oscillation frequencies are strongly associated with the density contrast between inner and outer core, determination of eigenfrequencies is highly important for geophysics, especially for understanding of earth's thermal and formational evolution. Many studies have surveyed Slichter mode, but no conclusive evidence was found, since the signal of Slichter mode is quite small (PREM predicts its amplitude: $\sim 10^{-14}$gal, 10^{-14}strain) and exists beside the other powerful signals such as tidal motions (M5 and M6).

In this study, we take much account for their oscillation directions, to pick out the inner core's weak signals. Since the Slichter mode is translational motion of the inner core, it has three oscillation components; one is the polar Slichter mode which is the motion of the inner core along the axis of rotation (Busse, 1974), the others are its orthogonal direction. Therefore, two oscillation directions at least may exist on an earth surface. But, many past researchers have surveyed only the radial directional signal, because high sensitivity gravity meter records were used. Then we used the multi-directional strain records which have high sensitivity on earth horizontal surface. Additionally, we used the strain analysis on the frequency domain (Okubo, 2007a), which named it the Fourier Strain Analysis (FSA), to determine the oscillation direction.

Finally we determined the Slichter mode of two eigenfrequencies (0.057 mHz and 0.051 mHz) that have enough Fourier amplitude and small FSA analytical error (Okubo, 2007b). In addition, we took full advantage of our records obtained by strainmeter that can respond until DC (= 0 Hz) signals and we determined decay rates (Q^{-1}) of Slichter oscillations, approximately 100 ~ 500.

Our results support the PREM (Dziewonski and Anderson, 1981) and the density contrast of inner and outer core is 600kg/m^3.

Key words: Slichter oscillations, Inner core, Fourier Strain Analysis, borehole strainmeter, and 2004 Sumatra earthquake.

Makoto Okubo studies the usage of the geodetical instrument, such as benioff type and borehole strainmeter, for seismological and geophysical research. He improved the 'strain analysis', which is ordinary strain analyzing method, to the 'streaming strain analysis' and 'Fourier strain analysis' for seismological usage. His new method can determine the location of epicenter, seismic moment and source time function of the earthquake. In this presentation, he will challenge to clarify the earth inner structure with another view point.

How can mapping seismic anisotropy of mantle lithosphere contribute to understanding of plate tectonics and deformation of continental lithosphere

J. Plomerová[1], V. Babuška[2]**,** L. Vecsey[3]

1. Geophysical Institute, Czech Acad. Sci., Prague, Czech Republic, jpl@ig.cas.cz
2. Geophysical Institute, Czech Acad. Sci., Prague, Czech Republic, v.babuska@ig.cas.cz
3. Geophysical Institute, Czech Acad. Sci., Prague, Czech Republic, vecsey@ig.cas.cz

ABSTRACT

Structure of the continental lithosphere records the geodynamic development of outer parts of the Earth driven by the mantle convection. At scale lengths of a few hundred kilometres, we recognize domains with a consistent large-scale orientation of seismic anisotropy in tectonically different provinces of the continental lithosphere. The orientation of seismic anisotropy often changes abruptly at mantle domain boundaries. We have found domains of mantle lithosphere with different fabrics in the massifs of the Hercynian belt in central Europe as well as in Precambrian Fennoscandia, though average isotropic velocities in different domains are often similar and their boundaries are thus masked in isotropic velocity tomography. Also, interpretations of lateral variations of seismic anisotropy in regions around subduction zones in the Mediterranean require considering not only effects of asthenospheric flow, but contributions from fossil anisotropy of the overlying continental mantle lithosphere. We invert and interpret jointly anisotropic parameters of body waves (P residual spheres and shear-wave splitting) for 3D self-consistent anisotropic models of the mantle lithosphere. Velocity anisotropy of lithosphere domains is approximated by hexagonal or orthorhombic symmetry of fossil olivine fabrics with generally plunging symmetry axes, while mostly sub-horizontal anisotropy due to the present-day flow is generally modelled in the asthenosphere below the continental plates. Though driving mechanisms of plate tectonics throughout the planet history are enigmatic, architecture of the continental plates can help to answer questions how and when the plates were assembled and to what extent they were later deformed. We interpret the anisotropic domains as fragments of mantle lithosphere retaining an old fossil olivine fabric, which was created before these micro-continents assembled. Dynamic forces acting in young orogenic regions with active tectonics could deform the mantle part of the lithosphere and thus partly re-orient fabrics. However, step-like relief of the LAB and variable fabrics even in the Precambrian lithosphere support the idea that fabrics of mantle lithosphere was formed during an early form of plate tectonics, e.g., by systems of successive paleosubductions (Babuška and Plomerová, 1989), or other subduction-related processes, like a thrust stacking of oceanic (proto-cratonic) lithospheres and accretion of magmatic arcs, acting since the Archean (Flowers et al., 2004; Condie et al., 2006).

Key words: Seismic anisotropy, P-wave tomography, shear-wave splitting, joint inversion

PRESENTER'S BIOGRAPHY

Jaroslava Plomerová was born in Czechoslovakia and graduated at Charles University, Prague in 1970. Since then she has been working in seismology with main focus on structure of the continental lithosphere, evaluating body-wave anisotropy (P-wave tomography, anisotropy, shear-wave splitting, joint inversion) and modelling the lithosphere thickness.

Seismic Core Reflective Phases Detected at Broadband and Short Period Arrays in Australia

Sara H. Pozgay, Hrvoje Tkalcic

The Australian National University, Research School of Earth Sciences, Canberra, ACT, 0200 Australia

Australia is not favorably positioned relative to most global seismicity for the recording of *PKP* waves at long epicentral distances. However, the surrounding seismicity and a large number of recorders present vast opportunities to record and study seldom observed core-sensitive phases, such as the whispering gallery of *P* waves that reflect from the lower side of the core mantle boundary (*PnKP* waves). Prior reports of these seismic phases recorded at analog stations during the sixties and the seventies suggest that digital recordings of these phases in Australia could be abundant, especially with the advent of newer signal processing techniques. In addition, the lack of anthropogenic noise for most stations, and the presence of low attenuation in parts of the upper mantle, enable good signal-to-noise ratio. In the last 10-15 years, short-period and broadband arrays have been deployed simultaneously throughout different parts of the continent, which increases the probability of observing complex core phases and provides a good basis for comparative analysis.

We design a procedure for detecting core-sensitive phases using seismograms recorded at different deployments. We search for *PcP* and *PnKP* in a systematic nature with a variety of techniques, such as sliding filters in the time domain and spectrograms in the frequency domain. In addition, utilizing the adaptive stacking method increases the visibility of the phases and aids in detection. Preliminary investigations of a partial dataset detect a significant number of arrivals. In particular, findings show several *P4KP* arrival times on the order of 5-10 sec earlier than predicted arrival times from *ak135*. A number of observed *P4KP* waveforms have smaller amplitude precursors several seconds prior to the main arrival. These precursors have the same slowness and similar frequency content as compared to the main arrival, all of which reinforces the precursory observation. We aim for further analysis of the *PnKP* and precursory arrivals toward interpreting the structure of the outer core.

The turbulence hypothesis – a different view to the global geodynamics

Boyko Ranguelov[1]

1. Geophysical Institute, Bulgarian Academy of Sciences,
Bulgaria,
branguelov@gmail.com

ABSTRACT

The main fundamental concept of this hypothesis is based on the assumption that rotational turbulence movements are the main elements of the global geodynamics and the structures developed on the solid Earth surface and in the Earth's interior during the Earth's history. They are called "corkings" and have different sizes, forms and velocities of the movements, consist of different branches with different vertical and horizontal displacements. Some of them are more active, some are calmer, but all have their expressions in the different geodynamic structures observed on the Earth's surface. This is a fully mobilistic concept. The direct analogy with the atmospheric turbulences and ocean flows is obvious and accepted. The main differences are the medium, where the turbulences originate and developed, (appearing and disappearing) and the velocities of the movements. The corkings and/or the different branches of the corkings themselves and the atmospheric turbulences, (respectively the ocean flows) are similar in their shape and forms. They are interacting as well as in similar way. They appear and disappear spontaneously in time. After being formed they have relatively stable development in the time domain to the moment they are destroyed or disappear. Corkings could penetrate deeper in the Earth's interior, or have shallower influence. Thus, in general the similarities between atmospheric (ocean) turbulences and the corkings are the shape, branching structure, different forms and sizes and the interactions between them. The corkings have the same properties as the atmospheric (ocean) turbulences – strongly expressed nonlinearity in their behavior and interactions, especially during the catastrophic phases of the Earth's development. The main differences are the substances they exist in, the velocity of the movements of the masses and the possibilities of axial position (usually the atmospheric turbulences have vertical or sub-vertical space position, but the ocean flows are more complicated having as well as relatively great horizontal components). Corkings due to the very high viscosity of the substance, where they exist in, may have not only the vertical, but even horizontal and/or sub-horizontal position. The probable main energy source (driving mechanism) of the movements and the generation of the corkings is the Earth's core, its perturbations and/or movements, balancing the stability and the space position of the Earth and acting as source of the different turbulences in the "solid" Earth. Many of the structures observed now on the Erath's surface could be the recent corkings, their branches and/or relicts of the existing earlier corkings. Many examples from the different fields of the knowledge on the Earth are presented. Summary data and information are compiled from the different fields of the geodynamics – recent GPS measurements, geophysical evidences like gravity field observations, seismic tomography, etc. and many geology evidences are incorporated as illustrations to this different view to the global geodynamics.

Key words: turbulence, hypothesis, global, geodynamics

PRESENTER'S BIOGRAPHY

Boyko Ranguelov

Seismologist, Senior Researcher in the Geophysical Institute of the Bulgarian Academy of Sciences. Areas of scientific interests: Seismology – Geodynamics, Nonlinearities, Seismic source modeling, Seismic zoning; Tsunamis – Cataloguing, Paleotsunamis, Refraction applications, Tsunami zoning; Geophysics – Data analysis and signal processing, Complexity; Natural Disasters – Damage estimations, Hazard Assessment; Environment – Environmental impacts by natural and man-made disasters, Protection and Prevention measures. Member of many scientific national and international boards. Honored by several foreign and international scientific awards. Participant in more than 200 international scientific forums – congresses, conferences, workshops, etc. Author and coauthor of more than 10 books, 250 scientific papers and reports, etc. Participant in more than 20 international and 50 national projects and expertise activities. Professor in two Bulgarian Universities – Mining and Geology and New Bulgarian. Visiting scientist for two years in the EU Join Research Centre and Bologna University. Member of the 10th National Antarctic expedition 2000-2001.

Regional body-wave tomography reveals a linear deep-seated low-velocity zone beneath the Cameroon Volcanic Line

Angela Marie Reusch[1], Andrew A. Nyblade[1], Douglas Wiens[2,]
Rigobert Tibi[3], Bekoa Ateba[4], Charles Tabod[5]

1. Pennsylvania State University, USA, AReusch@psu.edu
2. Washington University, USA, doug@mantle.wustl.edu
3. Schlumberger, USA, rigobert.tibi@yahoo.com
4. Institut de Recherches Geologiques et Minieres, Cameroon, atebs@yahoo.com
5. University of Yaounde I, Cameroon, charlestabod@yahoo.co.uk

ABSTRACT

Linear volcanic chains without age progression present challenges to current models of mantle dynamics. This study presents results from a seismic experiment to investigate the origin of the Cameroon Volcanic Line (CVL). The CVL is a 1600km feature traversing both continental Cameroon in west Africa and the offshore islands of Bioko (part of Equatorial Guinea), Sao Tome and Principe, and Annobon (also part of Equatorial Guinea). The CVL is a fairly linear feature, suggestive of the movement of the African plate over a stationary hotspot, but the volcanic rock ages of the CVL range from 42Ma to the present (with present volcanism occurring in the center of the line at Mt. Cameroon), contrary to what would be expected from a stationary hot spot. Several hypotheses have been proposed for the formation of the CVL such as multiple plumes, lateral flow from the Afar depression, and edge-flow convection initiated by the temperature differences between the mantle and the nearby Congo Craton

The Cameroon Seismic Experiment was deployed in Cameroon from January 2005 to January 2007, with 8 stations active the first year and an additional 24 stations installed in January 2006. The data from the 32 broadband seismometers has been used for a body-wave tomography study to examine upper mantle structure. Results from P- and S-wave travel time tomography show a steep-sided linear low-velocity anomaly directly beneath the CVL that extends from shallow mantle depths to at least 350km. Preliminary 1D results from the stacking of receiver functions to image mantle transition zone discontinuities suggest that this anomaly continues to greater than 500km depth. This finding suggests that the anomaly is not caused by regional flow patterns associated with the Congo craton or a single plume but instead might require a model invoking a linear sheet-like thermal upwelling in the mantle.

Key words: body-waves, tomography, mantle, plumes

PRESENTER'S BIOGRAPHY

Ms Angela Marie Reusch is a PhD candidate and AfricaArray student at Pennsylvania State University working under Dr. Andy Nyblade. She has a B.S. degree from Arizona State University in geology and a M.S. degree in geophysics from Virginia Tech. Working under Dr. Arthur Snoke, Ms. Reusch's M.S. thesis looked at the upper-mantle S-wave velocity structure beneath the Kaapvaal Craton using the two-station method for surface waves. Her PhD research is focusing on the upper 750km of the mantle beneath Cameroon in West Africa. She is using body-wave tomography in conjunction with receiver functions to constrain the low-velocity zone evident beneath the Cameroon Volcanic Line.

Recent geodynamic pattern of the northern and eastern parts of the Bohemian Massif based on GPS measurements

Zdeňka Schenková, Vladimír Schenk and Milada Grácová

Institute of Rock Structure and Mechanics, v.v.i., Academy of Sciences, Czech Republic
zdschenk@irsm.cas.cz, schenk@irsm.cas.cz, gracova@irsm.cas.cz

ABSTRACT

The Bohemian Massif is a Precambrian cratonic terrane composed mostly of highly metamorphosed rocks intruded by a series of granitoids. The Massif had been affected by several orogeneses that formed its tectonic pattern. To detect the recent geodynamic motions going on fundamental geological structures of the northern and eastern parts of the Bohemian Massif three regional geodynamic networks EAST SUDETEN, WEST SUDETEN and HIGHLANDS were established for epoch GPS measurements and one countrywide Geodynamic Network of the Academy of Sciences (GEONAS) for permanent GPS satellite signals monitoring. Special attention was devoted to mobility trends along the Marginal Sudetic fault, the Hronov-Poříčí and Jílovice fault zones, the Železné hory Mts fault zone and the Boskovice furrow. GPS measurements detected the sinistral movements on the NW-SE faults in the NE part of the Bohemian Massif, especially along the Marginal Sudetic fault. In the NE part of the Massif area, besides the sinistral movements on the Sudetic faults, also sinistral movements on the NNE-SSW faults of the Moravo-Silesian tectonic system have been observed. Because of an intersection of both tectonic systems nobody can exclude also an existence of dextral movements in this area. The GPS sites located in the Krkonoše Mts structural block display pronounce movements in the NW direction relating to neighbouring structures. Any change of movement trends can be explained by the zone location itself because of its position on opposite side of the Moldanubicum, the deepest structural block of the Bohemian Massif. When in the western marginal parts of the Moldanubicum the dextral movement trends have been detected, naturally then in the eastern marginal parts the sinistral trends can be expected. Sinistral movement trends dominate on many faults situated in close vicinity of the contact of the Moldanuabian and Lugian parts and the Moravo-Silesian part of the Bohemian Massif. Generally, the preliminary analysis of movements displayed that eastern part of the Bohemian Massif could be under "slight extending" trends. The detection of sinistral movements of 1÷2 mm/year along the faults situated between the Moldanubian and Moravian parts of the Bohemian Massif (area of the Boskovice furrow) verified the previous results obtained for the northern part of Moravo-Silesian structural block. It is evident that these preliminary detected movements have to be verified by other annual GPS measurements. Recent geodynamic motions determined on the base of satellite monitoring were compared also with earthquake occurrences. The work was supported by the Grant Agency of the Academy of Sciences of the Czech Republic (Project IAA300460507) and by the Ministry of Education, Youth and Sport of the Czech Republic (Projects LC506 and 1P05ME781).

Key words: GPS movements, the Bohemian Massif, structures, earthquakes

Zdeňka Schenková - RNDr (in mathematics), CSc (in seismology) - graduated at the Faculty of Mathematics and Physics, Charles University, Prague, Czech Republic, and defended the CSc degree at the Geophysical Institute, Academy of Sciences, Prague. After university studies she joined the Geophysical Institute of the Academy of Sciences and in 1995 she moved to the present Institute. Her research activities are: geodynamics and seismotectonics, earthquake hazard and seismic risk, seismicity, macroseismology and time-variable activity of seismogenic zones. She was in positions of the national and international organizations and she is the editor-in-chief of the journal Acta Geodynamica et Geomaterialia issued by the Institute of Rock Structure and Mechanics, Academy of Sciences of CR. She is the author more than 250 articles, editor of several special issues in professional journals and author of more than 70 research reports.

Towards modeling of global mantle convection with rheologically complex and fully 3D lithosphere and asthenosphere

Stephan V. Sobolev[1], Anton Popov[2], Bernhard Steinberger[3]

1. GFZ Potsdam, Germany, stephan@gfz-potsdam.de
2. GFZ Potsdam, Germany, anton@gfz-potsdam.de
3. NGU Trondheim, Norway, bernhard.steinberger@ngu.no

ABSTRACT

The convection in deep Earth is linked to the surface through the heterogeneous and rheologically complex lithosphere and asthenosphere, which are usually strongly simplified in global geodynamic models. In this project we use a newly developed 3D thermomechanical finite element numerical technique (Popov and Sobolev, PEPI 2008) to model a 300 km thick upper layer of the Earth in full 3D, coupled with the convecting mantle. The present day temperature distribution and crustal structure within the layer are taken from existing models: continental temperature from Artemieva (2006), ocean temperature based on ocean age, and the crustal structure from the Crust2 model. We assume that the upper layer is composed from non-linear temperature and stress dependent visco-elastic rheology, corresponding to the dry olivine (mantle) or naturally wet plagioclase (crust), combined with Mohr-Coulomb frictional plasticity. Plate boundaries are represented by the narrow zones of elasto-visco-plastic rheology with much lower friction than within the plates. The mantle below the 300 km depth is modeled using Hager and O'Connell's mantle flow spectral modeling technique with present day density and viscosity distribution from Steinberger and Calderwood (2006). The upper layer and mantle modeling domains are coupled by continuity of tractions and velocities at 300 km depth. Here we will show modeling results for the present day Earth structure focusing on the effect of the strength at plate boundaries on the plate velocities and stress distribution in the crust. Modeling shows that deep convection generates plate tectonic-like velocity pattern only when effective friction at subduction plate boundaries becomes less than 0.05. Both magnitudes and directions of plate velocities are reproduced very well at friction in subduction zones of 0.01-0.02 and friction at other plate boundaries of 0.05-0.1. Our models also demonstrate that velocities in the upper 300 km layer appear to be significantly depth-dependent, contrary to the basic assumption of the frequently used thin-shell global geodynamic models.

Key words: global geodynamic model, mantle convection, lithosphere, plate tectonics, tectonophysics.

PRESENTER'S BIOGRAPHY

Stephan V. Sobolev, PhD in Geophysics, Schmidt Institute of Physics of the Earth, Moscow, Russia. Currently head of the Section 2.5 "Geodynamic Modeling" at GFZ Potsdam, Germany.

MANTLE DISCONTINUITIES AROUND 410 KM DEPTH BENEATH CALIFORNIA.

Eleonore Stutzmann[1], Lev Vinnik[2], Yong Ren[3], Veronique Farra[4] and Serguey Kiselev[5]

1. Institut de Physique du Globe de Paris, France, stutz@ipgp.jussieu.fr
2. Institute of Physics of the Earth of Moscow, Russia, vinnik@ifz.ru
3. now at University of Rhodes Island, USA, ren@gso.uri.edu
4. Institut de Physique du Globe de Paris, France farra@ipgp.jussieu.fr
5. Institute of Physics of the Earth of Moscow, Russia, kiselev@ifz.ru

In order to study discontinuities in the deep upper mantle beneath California, nearly 5000 S receiver functions (SRF) have been computed for several tens seismograph stations. The S receiver functions are stacked in three back-azimuth sectors for single stations and small groups of neighboring stations. The S wave converted to P at the 410-km discontinuity can be clearly identified on most stacked S receiver functions. The corresponding wave paths sample the upper mantle beneath California and the Pacific margin. Almost all of the observed S410p arrivals are earlier than predicted by IASP91 model, with a representative value of the residual of about -2 sec. The early arrivals can be explained either by an anomalously high Vp/Vs velocity ratio in the upper mantle or by a depressed 410-km discontinuity or both. For many stacked S receiver function, we also observe phases converted from S to P at a negative discontinuity around 350km depth. These phases are indicative of a thin low-S-velocity layer atop the 410-km discontinuity beneath southern California and the neighboring oceanic margin. We also observe converted phases below the 410-km discontinuity which suggest the existence of a low S velocity layer in the mantle transition zone.

Key words: mantle discontinuities, low velocity layer, S receiver function

PRESENTER'S BIOGRAPHY

Eléonore Stutzmann

EDUCATION

- Habilitation, University of Paris VII.
- Ph.D. in Earth Science, University of Paris VII.
- Engineer diploma, Ecole et Observatoire de Physique du Globe, Strasbourg.

POSITIONS HELD

- Director of the GEOSCOPE observatory (2007-),http://geoscope.ipgp.jussieu.fr
- Physicist, Institut de Physique du Globe de Paris, France (2007-).
- Adjunct director of the seismological department , Institut de Physique du Globe de Paris, France (2003-2007)
- Associate physicist, Institut de Physique du Globe de Paris, France (1994-2007).
- Member of the GEOSCOPE program executive committee (1994-).
- Post doctorate, University of Utrecht, Netherlands (1993-1994).

RESEARCH INTERESTS

- Mantle geodynamic
- P-wave, S-wave and surface wave tomography to constrain mantle temperature and composition.
- Slab characterization: depth extent, temperature and composition
- Hotspot origin at depth and plume-mantle interaction.
- Seismic networks
- Ocean bottom observatories.
- Seismic noise sources.

Crustal elasticity contrast across the East Kunlun fault in northern Tibet inferred from InSAR measurements of the 2001 M_w7.8 Kokoxili earthquake

Wei Tao[1], Zhengkang Shen[1,2]

1. State Key Laboratory of Earthquake Dynamics, Institute of Geology, CEA, China, taoweibeijing@gmail.com
2. Department of Earth and Space Sciences, UCIA, USA, zshen@ies.ac.cn

ABSTRACT

We use coseismic deformation data of the 2001 M_W7.8 Kokoxili earthquake obtained from InSAR measurements to study crustal elasticity contrast across the East Kunlun fault. Coseismic deformation field of the earthquke documented by InSAR studies indicated that the displacements on the south side were 20%-30% higher than that on the north side of the fault. We develop an elastic finite element model and invert InSAR data from two deformation profiles to estimate two parameters: the Young's modulus contrast across the fault and the fault rupture depth. The starting lithospheric sturctural model is adopted from a seismic reflection study on the north side of the East Kunlun fault. Our result shows optimal estimates of the earthquake rupture depth as 20-22km and the curstal Young's modulus contrast between the south and north side as 81%-92%. Such a result, obtained from study of crustal deformation suggests a softer crust south than north of the fault, which is consistent with previous tomographic and magnetotelluric studies of a low-velocity and high-conductivity layer existing in lower crust of the Kokoxili-Qinagtang block south of the Kunlun fault.

Key words: InSAR, coseismic deformation, inversion, elasticity contrast, Tibetan plateau

Biography of Wei Tao

Wei Tao graduated with B.S. degree in Geophysics from the Department of Ocean Geology, Qingdao Ocean University in 1994. She received M.S. degree and Ph.D degree in Solid Geophysics from the Institue of Geology, China Earthquake Administration(CEA) in 1999 and 2003 respectively. Since 2004, she has been working for the State Key Laboratory of Earthquake Dynamics, Institue of Geology, CEA as an associate professor. Her research interests concentrate on Numerical Modelling in Geodynamics.

Inner Core Boundary Properties From PcP and PKiKP waves

Hrvoje Tkalcic[1], Vernon F. Cormier[2] and Brian L. N. Kennett[1]

1 Research School of Earth Sciences, The Australian National University, Canberra, ACT 0200, Australia

2 University of Connecticut, Physics Department, Storrs, Connecticut, United States

The inner core boundary of the Earth is characterised by a discontinuous change in elastic properties between the outer and inner core. The size and nature of this discontinuity provides direct constraints on the age of the inner core and the energy needed to sustain Earth's magnetic field. A measure of the density ratio at the inner core boundary is given by the amplitude ratio of P waves reflected by the outer core boundary (PcP) and inner core boundary (PKiKP). Furthermore, the absolute amplitudes of PKiKP were recently used to infer the existence of the so-called mosaic structure at the inner-outer core boundary.

We present high-quality observations of PcP and PKiKP waves originated from earthquakes and nuclear explosions. A new method that considers microseismic and event-generated noise is introduced for reliable measurements of absolute and relative amplitudes and their uncertainties. A number of numerical experiments were conducted to model the amplitude ratio (PKiKP/PcP), including a search for the mechanism for reproducing an observed anti-correlation of the amplitude of these wave types. Bounds were placed on the inner core discontinuity and a number of mechanisms were eliminated as an explanation for the anti-correlation of PKiKP and PcP amplitudes. We favour a mechanism of heterogeneity in earthquake and explosion radiation patterns that can selectively increase or decrease energy in the direction of the PcP or PKiKP wave because rate of change of PKiKP with increasing vertical take-off angle is opposite to that of PcP. Furthermore, the simultaneously observed amplitudes of PKiKP and PcP waves confirm that the CMB is a more complex boundary than the ICB.

Eulerian Plate Kinematics of East African Rift from earthquake data

Isaiah Tumwikirize [1] Ray Durrheim[2]

1Department of Geological Survey and Mines, P.O. Box 9, Entebbe, UGANDA. E-mail: isaiah.tumwikirize@gmail.com, isaiah_tumwikirize@hotmail.com

2 University of the Witwatersrand Johannesburg School of Geoscience. E-mail: rdurrhei@csir.co.za

Abstract

Based on Euler's theorem, kinematics of East African Rift System (EARS) from earthquake data between 20° S to 15° N, and 25° E to 45° E is presented. The active faults data and field observations from Global Positioning System (GPS) were used to compare results. The results obtained indicate average spreading rates in the range of 0.5 to 0.67 cm/year with a directional vector of 75° North-North-West for the African plate. However, the spreading directional vector does not show significant variation from South to Northwards until to about 7° N, where a decrease of at least 1° in the direction vector was observed. This anomaly may be associated with Afar triple junction. Further to the South, the spreading rates decrease and to the North, there are high spreading rate. This finding provides evidence to confirm that the continental rifting is propagating Southwards. And the kinematics analysis in EARS is complicated because both plates are in motion, but Euler's theory expects one plate to be on the move relative to the other. The results obtained in this paper compare well with GPS geodetic observation taken by measurements at fixed geodetic positions. However, it must be pointed out that the analysis of the kinematics of the EARS is complex because of its structural configuration. In a detailed analysis of the seismicity of the EAR, Gregory Rift (Kenya Rift) and the Western branch of the EARS demarcate a tectonic plate which is largely occupied by Ugandan territory. Although the spreading rate of 0.5-0.67 cm/year for African and Somalia plates were obtained; the findings in this paper remain consistent with the GPS observations. The velocity vector direction for plate motions is 75° NNW for the African plate and it is not reported in the previous studies. From geodetic observations and this paper, two extensional trends are observed: The movement of African plate is in the NNW and SSE for Somalia plate. The other trend is SSW for African plate and NNE for Somalia plate (SSW and NNE extension). The overall general rifting is trending in NNW-SSE extension. The earthquake activity in the EAR is largely controlled by the tectonics of African and Somalia plate. Using earthquake data it has been able to demarcate the complex configuration of the rift structures especially around Lake Victoria which are under researched.

Key words: Kinematics, Spreading, East Africa, Rift

PRESENTER'S BIOGRAPHY

Acting Coordinator Uganda National Seismological Network, Geophysicist, over 10 years experience in Geosciences work especially in seismic network operation, data processing analysis and interpretation and geothermal exploration. Education: B. Development Studies; BSc. (Hon) Geophysics, PGD Seismology. Membership: Eastern and Southern Africa Regional Seismological Working Group (ESARSWG); Uganda Seismic Safety Association and Society of Exploration Geophysicists (SEG).

The isostatic state of the African plate: Initial results

S. C. Werner[1], B. Steinberger[2], J. Ebbing[3], and the TAP Team

Geological Survey of Norway, Stephanie.Werner@ngu.no
Geological Survey of Norway, Bernhard.Steinberger@ngu.no
Geological Survey of Norway, Joerg.Ebbing@ngu.no

ABSTRACT

We have analysed the regional gravity field and isostatic state of the African continent and the work presented here forms part of a larger multidisciplinary project (TAP), which explores the evolution of Africa in time and space, and from the core-mantle-boundary to the surface. The topography of the Earth's surface is for long wavelengths (typically several tens to more than hundred kilometres) a response to forces applied on the lithosphere, including buoyancy forces. This response depends strongly on the density and rheology of the plate, and can be studied by careful analysis of the gravity field. With respect to global data sets, Africa has still many spots where the crustal thickness and the structure is unknown or only known with very large uncertainties. However, with satellite data and derived Earth gravity models, it is now possible to study the gravity field over the entire African plate with reasonable resolution on a crustal/lithospheric scales. Isostatic models based on surface topography allow a first-order characterization of the tectonic setting within the African plate, and comparison with global velocity and tomography models furthermore links the isostatic state to static and dynamic processes in the lithosphere.

In this study, we have utilized satellite gravity data and topographic information to evaluate existing crustal thickness models. We have also evaluated the isostatic state of the African plate, and analysed the static and dynamic contributions at the longer wavelength range. Separation of sources within or below the crust, as well as differences between modelled and observed gravity anomalies yield insight into tectonically and dynamically active areas within the African plate, which will be discussed in detail.

Key words: isostasy, Africa, crustal thickness, satellite