The intraplate seismicity of Namaqualand, South Africa: evidence for a long lived, anomalous stress field

Marco A.G. Andreoli[1], Johann Scheepers[2], Oliver Heidbach[3], Ingrid Stengel[4], Terence S. McCarthy[5], Alexandre Kounov[6]

1. Necsa, South Africa, marco@necsa.co.za
2. Impala Platinum, South Africa, johann.scheepers@implats.co.za
3. GeoForschungsZentrum, Germany, oheid@gpi.uni-karlsruhe.de
4. NamibGeoVista Geoconsult & Imaging, Namibia, ingrid@namibgeovista.com
5. University of the Witwatersrand, South Africa, mccarthyt@geosciences.wits.ac.za
6. University of Basel, Switzerland, A.Kounov@unibas.ch

ABSTRACT

The seismicity of the Namaqualand-Karoo region in South Africa displays typical intraplate features, namely events of low to moderate intensity, with a random scattering of epicenters distant from plate boundaries. Our study of this seismicity combines the seismic records from 1989 to 2008 collected by two seismometers (3-components TELS) located at Vaalputs with both on-shore and off-shore stress measurements (in mine, borehole breakouts), remote sensing and morphotectonic analysis, trench mapping, fault plane analysis and other techniques.

Our data indicate that even though many of the seismic epicenters are scattered, a significant number cluster along known or inferred faults. Important parameters that describe the seismicity of the Namaqualand seismic region within a radius of 100 km around Vaalputs are: average number of events/year ~12-15 (65 events swarm in 1996); b factor = 0.83 ± 0.07; recorded maximum magnitude M_{max} ~5.8. There is now compelling evidence that the Namaqualand seismicity is governed by a NNW-SSE oriented horizontal σ_1 typical of an Andersonian strike-slip ($\sigma_1 > \sigma_v > \sigma_3$) regime. This stress orientation, referred to in the literature as the Wegener stress regime/anomaly, extends over an area of at least 2 x 10^6 Km^2 in the western parts of southern Africa, possibly also including the adjacent offshore domains. Its intensity and general orientation display both spatial and temporal variability, e.g. decreasing toward the east (e.g. in the Witwatersrand basin) where $\sigma_v \geq \sigma_2 > \sigma_3$ and average σ_2 ~N280-290°. Wegener stress conditions were probably attained in the mid to Late Cretaceous (ca. 85±15 Ma) as indicated by kinematically compatible thrusting, reverse faulting and folding of Karoo and even younger sedimentary rocks in parts of Namibia (e.g.: Waterberg; forelands of Klein and Groot Karas Mts.), by respective drainage system trends and their re-orientation, by faulting along the Namaqualand escarpment, and by the orientation of swarms of Type I kimberlite dykes in the Kaapvaal Craton. Evidence for periodic suppression of the Wegener stress field may be inferred from ~NE oriented, 130-114 Ma Type II kimberlite dykes (Kaapvaal craton) and 70 – 67 Ma melilitite dykes (Vaalputs area). A similar, ~ENE orientation of S_{HMax} / σ_1 was also derived from slickensides on <65 Ma fault near Vaalputs. More recently, small thrust faults cutting the Late Pleistocene duricrust observed in trenches in the Vaalputs area suggest that central Namaqualand experienced renewed Wegener stress conditions between ~ 15ka and 8 Ka.

We conclude that seismicity of the Atlantic seaboard from Angola to South Africa is largely governed by the Wegener stress field. The origin of the latter is difficult to explain by numerical models based on the southerly propagation of the East African Rift because related strains may be traced tens of millions of years (mid-Cretaceous) before the beginning of rifting. Finally, because the stress anomaly is long lived and contemporaneous to an important cluster of (~80 Ma) kimberlite ages, it is likely to have affected the deep lithosphere too. More intriguingly, the Wegener stress field overlaps the deep (D”) thermochemical plume held responsible for the African Superswell.

Key words: Namaqualand, Seismicity, Stress, South Africa, Namibia.

Marco Achille Giacomo Andreoli

Born near Ferrara, Italy, in 1946, **Marco Andreoli** obtained his Italian Laurea (a M. Sc. Degree equivalent) in Geology from the University of Torino in 1970 and his Ph. D. (Geology) in 1982 at the University of the Witwatersrand. Marco has pursued a research career within the South African Nuclear Energy Corporation (Necsa), being responsible for geological investigations in radioactive waste disposal. In addition to neotectonics, Marco’s other interests include meteorite impacts (Morokweng), the behavior of radioactive elements in granulites and in groundwater, and the tectonic setting of the Bushveld Complex. Married to Eileen, with two children, Marco is Fellow of the School of Geosciences at Wits, of the Geological Society of South Africa, and a member of Academy of Science of South Africa.

Earthquake swarms in western Bohemian Massif (central Europe): intraplate, but sitting at paleoplate junction

V. Babuška[1]**,** J. Plomerová[2]

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

ABSTRACT

Geodynamic activity in the region of west Bohemia (Czech Republic) and Vogtland (Germany) is characterized by re-occurrence of earthquake swarms, mostly of magnitude $M_L < 3.5$ at focal depths between 4 and 20 km (Horálek and Fischer, Studia Geoph. Geod. 2008). The region is also known by several Quaternary volcanoes and by present-day high gas flow manifested by moffetts rich in CO_2 and helium of mantle origin (Weinlich et al., Geochim. Cosmochim. Acta 1999). We suggest that positions of the seismic and volcanic phenomena correlate with a ”triple junction” of three mantle lithospheres distinguished by different orientations of seismic anisotropy consistent within each unit (Plomerová et al., GJI 2007). The three mantle domains most probably belong to the originally separated micro-plates - the Saxothuringian, Teplá-Barrandian and Moldanubian - assembled during the Hercynian orogeny. Cenozoic extension reactivated the junction and locally thinned the crust and mantle lithosphere. The rigid part of the crust, characterized by the presence of earthquake foci, decoupled near the junction from the mantle probably during the Hercynian orogeny. The boundaries (transitions) of the three mantle domains provided open pathways for Quaternary volcanism and the ascent of ^{3}He- and CO_2-rich fluids released from the asthenosphere. The deepest earthquakes, interpreted as an upper limit of the brittle-ductile transition in the crust, are shallower above the junction of the mantle blocks (at about 12 km) than above the more stable Saxothuringian mantle lithosphere (at about 20 km), probably due to a higher heat flow and presence of fluids (Babuška et al., J.Geodyn. 2007). We suggest that many intraplate earthquakes in other continental regions may also be located at more or less healed paleoplate boundaries.

Key words: earthquake swarms, rejuvenated paleoplate junction

PRESENTER’S BIOGRAPHY

Vladislav Babuška, senior scientist with major research interests in seismic anisotropy and deep structure of continental lithosphere, chairman of the Czech National IUGS Committee. Graduated at Charles Univ., Prague (1960 and 1967), research fellow at Harvard Univ. (1969-70), visiting professor at Nagoya Univ. (1973) and Univ. Louis Pasteur, Strasbourg (1989). From 1992 to 1999 Secretary of the International Geoscience Programme at UNESCO, Paris.

Intraplate seismicity in Brazil, the case of Porto dos Gaúchos seismic zone in the Amazon Craton

Lucas Barros (1), Marcelo Assumpção, (2) Ronnie Quintero (3) and Ranielle Paz (4)

1. Seismological Observatory - University of Brasília, Brazil, lucas@unb.br
2. IAG - University of São Paulo, Brazil, marcelo@iag.usp.br
3. OVISICORI - UNA, Costa Rica, rquinter@una.ac.cr
4. Seismological Observatory – University of Brasilia, Brazil, ranipaz@brturbo.com.br

Brazilian seismicity is lower than in other mid-plate regions such as Eastern North America, India, and Australia, where magnitudes larger than 7 have been observed. Mid-plate seismicity in Brazil presents only 20 cases of earthquakes with magnitudes 5.0 m_b and above, two of them exceeding 6.0 (6.1 m_b in continental margin and 6.2 m_b in continental crust). A half of the epicenters lie close to the coast and the continental shelf and have been attributed to a combination of weakness zones (extended crust beneath the continental shelf) and amplification of the regional stresses due to local forces such as crustal inhomogeneities at the continent/ocean transition and flexural stresses due to loading of the sediments in the transition coast-ocean. Another half of epicenters lie in the continental crust, three of them, included the biggest and 5.2 (in 1998) and 5.0 (in 2005), in the Porto dos Gaúchos Seismic Zone (PGSZ). This seismic zone is located in the center north of Phanerozoic Parecis basin; such sediments overlay the crystalline basement of Amazon craton. Despite the mid-plate earthquakes in Brazil have not exceeded magnitude 6.2 $\mathbf{m_b}$ intensities up to VI and VII are not uncommon and make seismic risk evaluation an important issue in projects of critical facilities such as nuclear installations and hydroelectric power plants. Recently, this issue has received from government authorities special attention, particularly after the occurrence of the first fatal victim in the country caused by an earthquake of 4.9 mb and VII MM, occurred in December 7 of 2007, in the meddle of São Francisco craton, an area where it was never observed seismic activity before. As an immediate result of this scenery, in the next two years, will be deployed sixty new broadband permanent stations in Brazil and seismic hazard studies has received increased attention from government authorities, universities and associations of structural engineers.

The explanation of all intraplate earthquakes remains a challenge for seismologists, because most of the time, it is not possible to associate these earthquakes to any geological structure identified by various investigative techniques. The PGSZ is no different; the main graben and host system present in the Phanerozoic Parecis basin does not seem to be correlated with the recurrent seismicity that has been observed in the area since 1955. While the graben and host system present in the Parecis basin is aligned in a trend WSW-ENE, composite focal mechanisms studies carried out in two seismic sequences in PGSZ (1998 and 2005), reveal for both cases a mainly strike-slip faulting regime in SSW-ENE trend. Although no correlation is found between seismicity in PGSZ and buried graben existing in the area the maximum horizontal stress (SHmax) is probably E-W oriented, which is consistent with the expected stress direction from the theorical model proposed by different actors. The objective of this paper is to present a brief review of the Brazilian seismicity and discuss the recurrent seismicity in PGSZ based in new catalog of seismicity in stable continental region.

Key words: Brazilian seismicity, intraplate seismicity, mid-plate region.

PRESENTER'S BIOGRAPHY

Mr. Barros works at the Seismological Observatory of the Brasília University. He is graduated in electronic engineering and has Master degree in telecommunications engineering. Now, he is preparing his PhD thesis in the seismology field, studding the recurrent seismicity observed in Porto dos Gaúchos Seismic Zone, located in the Amazon craton, Brazil.

Coseismic reactivation of the Samambaia fault in northeastern Brazil

Francisco H.R. Bezerra[1], Maria O.L. Sousa[1], Joaquim M. Ferreira[2], Aderson F. do Nascimento[2], Francisco C.C. Nogueira[1]

1. Department of Geology, Federal University of R.N. state, Brazil, bezerrafh@geologia.ufrn.br, molucena@geologia.ufrn.br, frcezar@geologia.ufrn.br

2. Department of Geophysics, Federal University of R.N. state, Brazil, joaquim@dfte.ufrn.br, aderson@dfte.ufrn.br

ABSTRACT

Northeastern Brazil, within the South American plate, is under E-W-oriented compression and strike-slip faulting regime. Seismic activity in this area is known since 1724 and has been mainly characterized by earthquake swarms that can last ten years and events up to 5.2 m_b. Earthquakes have occurred in the upper crust at depths less than 12 km. Our study area is located at the border of the Potiguar basin, that, within the present knowledge of historical and contemporary seismicity, is one of the most active areas in intraplate South America. We compared aftershock sequences with ductile and brittle fabrics, and aeromagnetic data in the João Câmara (JC) epicentral area in an attempt to understand the local control of seismogenic faulting. The absence of surface deformation in JC area initially suggested that seismicity was caused by a blind fault. In the last two decades we obtained better hypocentral locations and well-constrained focal mechanisms, derived from temporary seismic networks. They led to new correlations among seismicity and preexisting geological and geophysical features. In the JC area, the seismogenic Samambaia fault forms a cluster of epicenters closely confined to a 27 km long linear zone, which trends 37° azimuth, dips 76°–80° to NW, and forms an alignment that cuts across the NNE-trending ductile Precambrian fabric. The depth of these events ranged from ~1 km to ~9 km. The fault forms an echelon array of three main left-bend segments. The seismicity spatially coincides with quartz veins and silicified-fault zones and a major aeromagnetic lineament. We observed at least two phases of quartz veins and two additional phases of fault silcification, associated with chalcedony and opale, in the seismogenic fault zone. We interpreted these superposed Si-features as the expression of an ongoing fluid-driven fault. In addition, the most intriguing aeromagnetic feature is a steeply dipping low-magnetic zone flanking the Samambaia fault down to 16 km deep. We speculate that this low magnetic zone may represent a channel rooted in the middle crust, where fluids ascent occurred along the fault zone. On the basis of seismological, geological, and aeromagnetic evidence, we suggest that the reactivation of the Samambaia fault, driven by high-fluid pressure, has occurred repeatedly through time, which we interpreted as the local control of coseismic faulting in JC area. Our findings support a tectonic inheritance model in which the seismicity is controlled by tectonic reactivation of preexisting structures in the crystalline basement. It follows that in many cases, studies in continental intraplate South America claiming lack of correlation at the scale of an earthquake rupture stem, in our opinion, from poor information on surface geology and deep geophysical features.

Key words: Intraplate setting, Brazil, Fault reactivation, fluids.

PRESENTER'S BIOGRAPHY

Francisco Hilario Bezerra
Bezerra is a geologist who teaches BSc and Graduate geology courses at the Federal University of Rio Grande do Norte, Brazil, where he is a Lecturer at the Department of Geology. His main interests are deformation of Cenozoic deposits, seismogenic faults, and tectonic stresses. Academic degrees: PhD, 1998, University College, London UK; MSc, 1992, University of Brasília, Brazil; BSc, 1987, University of Rio Grande do Norte, Brazil. He has recent publications on neotectonics and seismogenic faults in Geology, Tectonophysics, Journal of Geophysical Research, Geomorphology, Marine Geology, and Journal of South American Earth Sciences. He has received research grants mainly from the Brazilian Research Council (CNPq) and the Brazilian State Oil Company (Petrobras).

The seismicity associated to the December 9, 2007 Caraíbas-Itacarambi (4.9 mb) intracratonic earthquake (Minas Gerais, Brazil) and geophysical aspects

Cristiano Chimpliganond[1], Mônica Von Huelsen[2] ,George Sand França[3], Marcelo Assumpção[4], Augusto C. B. Pires[5]

1. Seismological Observatory - University of Brasília, Brazil, naibert@unb.br
2. Seismological Observatory - University of Brasília, Brazil, georgesand@unb.br
3. Seismological Observatory - University of Brasília, Brazil, monisis@unb.br
4. IAG - University of São Paulo, Brazil, marcelo@iag.usp.br
5. IG - University of Brasília, Brazil, acbpires@unb.br

ABSTRACT

On December 9, 2007, at 00:03 (local time), a 4.9 mb earthquake occurred at the small village of Caraíbas, near the city of Itacarambi, located at the northern part of Minas Gerais, in the São Francisco Craton. The maximum intensity reached VII Modified Mercalli and the isoseismal of VI MM intensity comprises an area of about 100 square kilometers. This event was the first in Brazil to cause a fatal victim. The events at this area started to be felt by the local population on May 25, 2007, when a 3.5 mb earthquake was widely felt and produced some damage to the buildings. A field campaing was taken during October 2007 to implement a local seismographic network composed by 6 tri-axial broadband stations that operated until August 2008. A seismic quiecence was observed some days before the mainshock, which was preceeded by three imminent foreshocks and followed during the first day by 162 foreshocks. A data set of earthquakes with clear onset times for P and S waves were located using Hypo71 using a local velocity model with a Vp/Vs ratio of 1.72, obtained with a composite Wadati diagram. The events show a trend in the NE-SW direction, with hypocenters shalower than 1 km dipping to E. A composite focal mechanism, determined using P-wave polarities with the clearest waveforms at local stations, shows a reverse faulting mechanism. A similar solution was obtained for the December 9, 2007 mainshock using both local and regional P-wave polarities. Geological data from the epicentral area shows the presence of undeformed limestone overlying the basement of the São Francisco craton. There are maped structural lineaments only about 40 km south of the seismogenic area that show NE-SW trending. Geophysical data sets from an airborne magnetic survey deployed at the northern part of Minas Gerais were processed and interpreted using state-of-the-art techniques. The data sets consist of 625 kilometers of profiles, spaced 250 m apart with direction N30W, covering an area of 140 square kilometers, including the study area. Some products were obtained by magnetic processing (e.g. amplitude and phase of analytical signal, vertical and horizontal derivatives, Euler deconvolution) that were used during the interpretation proccess to yield the identification of magnetic units and structures. The integration of geophysical information leads to a better picture of the spacial structural framewok of the surveyed area. The magnetic anomaly map shows that the epicenters are inserted among two magnetic structures of minimum extension of 17 km with direction NW-SE. The epicentral area is located inside of a magnetometric context where the magnetic relief is characterized by small wavelengths with NE-SW direction. The vertical derivative and upward continuation maps show that the seismogenic area is dominated by shallow magnetic structures. The magnetic structures trending NE-SW, show good agreement with the epicentral distribution and focal mechanism solutions.

Key words: Seismology, geophysics, Caraíbas-Itacarambi, intracratonic seismicity, magnetic structures.

PRESENTER'S BIOGRAPHY

Mr Cristiano Chimpliganond received his B.Sc. in Geology in 1997 and his M.Sc. in Seismology in 2003. Now he is a PhD student in Seismology at University of Brasília and has been working at Seismological Observatory since 1994 with natural and induced seismicity. His PhD project is related to detailed information of Caraíbas-Itacarambi intraplate seismicity, mainly hypocentral and source parameter determinations and stress distribution.

Seismicity of the Southeastern Brazilian Continental Margin and the recent magnitude 5 earthquake in the Santos Basin

João Carlos Dourado[1], Marcelo Souza de Assumpção[2]

1 – UNESP, Brazil, jdourado@rc.unesp.br
2 – USP, Brazil, marcelo@iag.usp.br

ABSTRACT

The majority of the earthquakes along the Brazilian Continental Margin are located offshore in the south and southeast of the country. Of the ten largest intraplate earthquakes in the country, four occurred in this region. The largest earthquakes in the SE continental shelf were: a magnitude 5.5 mb in 1939 offshore of Tubarão (Santa Catarina state); a magnitude 6.1 mb, offshore of Espirito Santo state in 1955; an event with 4.7 mb offshore of Rio de Janeiro in 1972.; a magnitude 5.2 occurred in Rio Grande do Sul in 1990. Recently, in April 24, 2008, an event occurred in the Santos basin, 250km south of São Vicente (Sao Paulo state) with a magnitude 5.2 mb. Instrumental and historical data of the Brazilian Seismic Bulletin shows that an earthquake larger than 5 mb occurs every 15 to 20 years. Small events, with magnitudes larger than 3, occur about three times per year.

Unfortunately, most of the previous events do not have the focal mechanism well determined because of the small magnitudes and the lack of seismic stations near the continental margin. Analyses of teleseismic records of three previous events (magnitudes ~5 mb) showed they all had reverse faulting mechanisms but the orientation of the nodal planes (and the P axes) were not well constrained. Therefore, the seismicity in the SE continental shelf is caused by predominantly horizontal compressional stresses, although the SHmax orientation is not well defined.

The focal mechanism solution of the recent April 2008 event, on the other hand, was well determined with both regional and teleseismic stations. The depth phase pP was well identified and gives a 17km focal depth, 7 km beneath the 10 km thick sedimentary pack, in an area of the Santos basin where the crustal thickness is 20 km. The P axis is NE oriented; both the P and T axes dip 45^o. One of the nodal planes is vertical with a strike in the NS direction; the other nodal plane has an E-W strike and a shallow dip towards the South. Although all previous events with ~5 mb occurred in areas of deep water (2km or more) of the continental slope, the 2008 event occurred in shallow water (~200m) just before the continental slope.

The tectonic mechanism causing intraplate seismicity is not yet fully understood and different models have been proposed. For continental margin seismicity, the following mechanisms have been suggested:
1) Response to local flexural stresses (due to the sediment load along the continental shelf and slope) associated with a weakened crust due to pre-rift lithospheric stretching during the separation process between South America and Africa (Assumpcao, 1998).
2) Compressional stresses from combined regional forces such as ridge-push from the Mid-Atlantic and collisional forces from the convergence between the Nazca and South American plates.
3) Rupture and collapse of oceanic lithosphere due to the ageing process and increased density.

The focal depth (lower crust) and dipping orientation of the P and T axes of the recent Sao Vicente earthquake are consistent with the expected stress directions in the lower crust caused by flexural forces if we assume the epicenter lies landwards of the main sedimentary load along the continental slope.

Key words: intraplate seismicity, Brazilian Continental Margin, Santos Basin seismicity.

JOÃO CARLOS DOURADO received his B. S. in geology from University of São Paulo in 1977 and Ph. D degree (1997) in Geosciences from the São Paulo State University - UNESP, Brazil. He worked with applied geophysics in Institute for Technological Research of the State of São Paulo - IPT (1977 to 1997). He joined the UNESP (São Paulo State University) in 1977 and currently he is Professor of geophysics at Department of Applied Geology. He works in application of geophysical methods with focus in: applied geophysics and seismology.

Recent intraplate seismic activity in NE Brazil

J M Ferreira[1], A F do Nascimento[1], F H R Bezerra[2], M O Souza[2], H C Lima Neto[1], C S Vilar[1]

1. Department of Geophysics, Federal University of R.N. State, Brazil, joaquim@dfte.ufrn.br, aderson@dfte.ufrn.br, helenocarlos@gmail.com, vilar@dfte.ufrn.br

2. Department of Geology, Federal University of R.N. State, Brazil, bezerrafh@geologia.ufrn.br, molucena@geologia.ufrn.br

ABSTRACT

Over the last 30 years, northeastern Brazil has experienced intraplate earthquakes with magnitude equal greater or than 5.0 mb (5.2, 1980; 5.1, 1986; 5.0, 1989). However, from 1991 until 2005, no event was recorded with magnitude equal or greater than 4.0 mb. Seismic activity in this region is maily concentrated at the border of the Potiguar Basin, northwestern Ceará State and at the Pernambuco Lineament. This on-going seismic activity has been reported in the region since 1808. Despite the fact that, until now, no catastrophic earthquake has occurred, two features of the seismicity in northeastern Brazil make the effects of the seismic events more pronounced: 1 — the seismic activity is concentrated in the shallow portions of the crust (up to 12 km depth) and 2 — the seismic activity usually occurs as swarm-like activity lasting, in some cases, for many years. Since 2005, this on-going seismic activity was recorded regionally and, in some cases, it was possible to deploy local seismographic networks and therefore accurate hypocentral parameters were determined. In this work, we present the result of the data analysis which gives us a regional idea of the recent seismic activity in northeastern Brazil.
Key words: Intraplate setting, seismology, continental crust, seismicity, tectonics.

PRESENTER'S BIOGRAPHY

Joaquim Mendes Ferreira
Joaquim Mendes Ferreira earned his first BSc in Physics at Univ. Estadual de Campinas (UNICAMP) in 1971. Then he had his MSc and PhD earned São Paulo University in 1983 and 1997. He is a adjoint Professor at Universidade Federal do Rio Grande do Norte since 1976. His main research interest are seismotectonics, historical seismicity and intraplate seismicity. He has authored several international publications and reports for Governmental bodies in Brazil. He has received research grants mainly from the Brazilian Research Council (CNPq), Brazilian State Oil Company (Petrobras) and the Brazilian Geological Survey (CPRM).

Characteristics of Australian Earthquakes

Gary Gibson[1,2]

1. Monash University, Australia, gary@earthquake.net.au
2. Environmental Systems & Services, Australia, gary.gibson@esands.com

ABSTRACT

Development of seismicity models for earthquake hazard studies in intraplate regions like Australia provides opportunity to learn much about local earthquake processes, in turn leading to improved hazard studies and other risk mitigation measures.

Australian earthquake hazard studies have been through several generations since the first national hazard map was published in 1976. In the most recent generations, the overall average hazard has not varied greatly, but higher resolution seismicity models with many active faults have produced greater variation in ground motion over relatively small distances. Active faults in intraplate regions are much less active than those at plate boundaries.

Australia is in a unique situation, being a stable intraplate region with extremely active northern and eastern boundaries. Tectonic stress levels are very high, dominated by strong horizontal compression and reverse faults, resulting in many effects. These include major problems in underground mining with triggered and induced earthquakes, and a high proportion of large water reservoirs giving reservoir triggered earthquakes. Earthquakes can be very shallow, and small events at depths within 1 km of the surface often occur and are reported felt within only a very small area. Shallow earthquake swarms often occur. A magnitude 4.1 earthquake in 1994 at a depth of 800 metres gave a peak ground acceleration of 0.97 g at a distance of 1 kilometre, but caused negligible damage due to the high frequency of motion and short duration. A magnitude 5.6 earthquake at Newcastle in 1989 caused 13 deaths and over A$1.5 billion insured damage plus a similar value of uninsured damage. Most events larger than magnitude 6.5 produce surface ruptures.

Because intraplate earthquakes have sparse recurrence in space and time, such lack of clutter in the seismicity provides an excellent opportunity to study earthquake clustering. Precursory activity has been noted during one to ten years before most Australian earthquakes larger than magnitude 6.0. Then, following the normal aftershock activity, a lower level of adjustment activity occurring over tens to hundreds of years is more apparent than in active regions.

A series of seismotectonic models, AUS1 through to the current development of AUS6, has gradually increased the resolution of the anticipated locations of possible future earthquakes. The models are increasingly dependent on geological input, and neotectonic activity is helping to bridge the scale differences between models based solely on past seismicity, and the perspective of most field geologists.

Although Australian earthquakes are almost all in the upper crust, their depth distribution varies, with maximum depths depending local geology. There is significant variation in both source properties and recurrence parameters with depth, with a larger proportion of small events occurring near the surface, while larger events tend to be at mid-range depths to deep.

Key words: Australia, seismicity, clustering, variations with earthquake depth

PRESENTER'S BIOGRAPHY

Gary Gibson established the Seismology Research Centre at RMIT University in Melbourne during 1976 and over the following years built a network of over 100 seismographs in eastern Australia. Since semi-retirement, this network is operated by Environmental Systems and Services in Melbourne, where he works part-time. He is an Honorary Research Fellow at Monash University. His interests are in observational seismology and its practical problems, particularly earthquake risk mitigation. Specialisations include local earthquake seismograph networks; local, regional and global seismicity; earthquake hazard evaluation; dams and earthquakes; reservoir triggered and mining induced seismicity; earthquake aspects of offshore oil and gas developments; earthquake preparation, alarm and response systems. He is currently chairman of the executive committee of the International Seismological Centre.

Seismicity studies for long-term seismic hazard assessment in the Northern Ontario part of the Canadian Shield

S.J. Hayek[1], J.A. Drysdale[1], **John Adams[1],** T. Lam[2], S. Halchuk[1], and V. Peci[1]

1. Canadian Hazard Information Service, Geological Survey of Canada, Ottawa, Canada. jadams@nrcan.gc.ca
2. Nuclear Waste Management Organization, Toronto, Canada

ABSTRACT

A seismic monitoring program was initiated in 1982 to document earthquake activity in the northern Ontario portion of the Canadian Shield, a region with very low rates of seismicity. The motivation is the need to quantify seismic hazard in this nearly aseismic region, in order to provide seismic hazard estimates for high-reliability structures (probabilities needed at $\sim 10^{-4}$ p.a. and lower). The initial two analog stations have grown to 26 digital stations covering the area, delivering continuous data in real-time via satellite. Over the past 25 years, more than 740 earthquakes were located in the region with magnitudes ranging from 0.5 to 4.3. These earthquakes had to be discriminated from the many mining-related events: since the study began, more than 1360 rockbursts and 4730 blasts have been located and identified, a mere sample of the actual activity. The detailed monitoring has (i) dropped the completeness threshold for magnitude of events from 3.5 to 2.0, (ii) established the rate of Ms > 4 events as 0.04 per annum for a 1.4 million square kilometre area; (iii) established the b-value of 1.12; (iv) used Rg-phases and Ma's Regional Depth Phase Method to determine earthquake depths; (v) identified a non-random distribution of events and confirmed that much activity occurs as shallow swarms; (vi) identified regions where the earthquakes depths are shallow (<6 km) and others where the depths are deep (5-17 km). These results feed into the seismic hazard analysis in the following way (i) the local b-value and rates of activity can be compared with average global rates for Stable Continents; (ii) seismic hazard in the regions of shallow earthquakes is higher than if default depths of 10 or 18 km were used; (iii) regions of deep earthquakes suggest reactivated fault zones more likely to generate large earthquakes.

Key words: seismic hazard, stable craton, seismic monitoring, Rg,

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.

Intraplate earthquake swarms in the western part of the Bohemian Massif (Central Europe): the space-time foci distribution, source mechanisms, and possible triggering mechanisms and driving forces

Josef Horálek[1], Tomáš Fischer[2],

1. Institute of Geophysics, Acad. Sci., Czech Republic, 141 31 Praha, jhr@ig.cas.cz
2. Institute of Geophysics, Acad. Sci., Czech Republic, 141 31 Praha, tomfis@ig.cas.cz

ABSTRACT

The western part of the Bohemian Massif (Central Europe) is a typical intraplate earthquake swarm region related to the Quaternary volcanism, which was active there until the Holocene. In addition, the region is characteristic by "fluid activity"manifested by a few moffetes and several hundred carbonized mineral springs and CO_2 vents. Periodically reoccurring earthquake swarms, mostly of magnitude $M_L < 3.5$, cluster predominantly in a few focal zones. The main focal zone Nový Kostel, where more than 90% of the total seismic moment has been released in last 25 last years, is of pronounced planar character of about 12 x 4 km at depths between 6 and 11 km. Two larger swarms and more than thirty swarm-like sequences (micro-swarms) occurred there since 1991.

The two recent swarms, which occurred there in January 1997 (nearly 800 $M_L \leq 3.0$ events) and in September to December 2000 (more than 20 000 $M_L \leq 3.5$ events), were located about 1 km apart. These swarms evinced strong time and space clustering, pronounced migration of the foci, and an apparent causality among swarm events revealed by the *b*-values of the frequency-magnitude distributions equal ≈1 and interevent time distributions abiding by the power law of T_w^{-p}. Nevertheless, the swarms show numerous significant dissimilarities implying their different evolution. The 2000-swarm consisting of nine distinctly separated phases was wholly located at the MFP, whereas that of 1997 was of the two-phase character and took place in the two-arm cluster located across the MFP. Source mechanisms (in the moment tensor description) also noticeably differ. Those of the 2000 swarm are cognate and show oblique normal or strike-slip faulting, whereas during the 1997-swarm two different mechanisms occurred: oblique normal faulting with a pure double-couple source (during the 1st swarm phase) and oblique thrust faulting with non-double-couple source (during the 2nd swarm phase). Space and time distribution of the consecutive 2000-swarm events indicates a relevance of the Coulomb stress redistribution that results in the self-organization of the swarm activity, while the space-time development of the 1997-swarm is indicative of presence of the high-pressured crustal fluids, which brought the fault close to its critical state and thus facilitated origination of the oblique thrust, non-DC events in the 2nd phase of the swarm. Thus we infer that in the West Bohemia/Vogtland earthquake swarm region crustal fluids play a key role in the alteration of the pre-existing favourably oriented faults from subcritical to critical state due to pore pressure increase. After bringing the fault to instability, the swarm activity is mainly driven by the Coulomb stress redistribution; crustal fluids keep the fault in a critical state.

Key words: western part of the Bohemian Massif, earthquake swarms, crustal fluids, triggering of earthquakes, models of earthquake swarms

PRESENTER'S BIOGRAPHY

Josef Horálek

Josef graduated from the Czech Technical University, and holds the PhD degree from the Czechoslovak Academy of Sciences in geophysics. Since 1973 he has been working in the Geophysical Institute of the Academy of Sciences of the Czech Republic in Prague, in department of seismology; currently he works as a Senior Researcher. His major subject field in the last fifteen years has been intraplate West Bohemia/Vogtland earthquake swarms. His recent investigations have been mostly aimed at triggering mechanisms and driving forces of earthquake swarms, and at the role of crustal fluids in the earthquake origination. This is reason why he also deal with earthquake sequences induced during the injection and circulation experiments at the HDR site Soultz-sous-Forest in France.

Recent Large Stable Continental Earthquakes in India

J.R. KAYAL

School of Oceanographic Studies, Jadavpur University, Kolkata 700032, India;
email : jr_kayal@hotmail.com

ABSTRACT

During the last decade, three devastating earthquakes, the Killari 1993 (m_b 6.3), Jabalpur 1997 (m_b 6.0) and the Bhuj 2001 (M_w 7.7) occurred in the Stable Continental Region (SCR) of peninsular India. These earthquake sequences shed new light in understanding tectonics and active faults in the SCR source regions.

The 1993 Killari Earthquake (m_b 6.3)

The September 30, 1993 Killari earthquake (m_b 6.3) occurred in the Deccan province of central India; the maximum *intensity* VIII (MSK scale) was estimated. The Killari earthquake and its 150 well located aftershocks were confined to a shallower depth (0-15 km), a common type of SCR seismicity. The main shock occurred by reverse faulting at a depth of 6 km; the deeper (6-15 km) aftershocks also occurred by reverse faulting. The shallower aftershocks, (0-<6 km), on the other hand, occurred by right-lateral strike-slip faulting. The Killari earthquake sequence is explained by a fault interaction model. *Seismic tomography* study revealed a detailed velocity structure of the source area; the main shock occurred at the contact zone of a high velocity and low velocity zones.

The 1997 Jabalpur Earthquake (m_b 6.0)

The May 22, 1997 Jabalpur earthquake (m_b 6.0), maximum *intensity* VIII (MSK scale), occurred at the base of the Narmada Rift Basin, within the SCR at a depth of 35 km by reverse faulting with a left-lateral strike-slip motion. Only about 25 aftershocks were recorded that occurred at depth 35-40 km in the lower crust. The fault-plane solution of the aftershocks also reveals reverse faulting with left-lateral strike-slip motion. The south dipping Narmada South Fault, the southern margin fault of the Narmada Rift Basin, was activated by reverse faulting. Seismic tomography study of the source area could not be done due to meagre aftershock data. Aftershock investigation, however, confirms the deeper source of the earthquakes

at the base of the paleo-rift basin. The basin that was formed in a tensional regime in the geological past now reactivates its deep rooted mantle reaching fault by inverse tectonics.

The 2001 Bhuj Earthquake (M_w 7.7)

The most recent devastating Bhuj earthquake (M_W 7.7) of January 26, 2001 is one of the rarest and largest events that occurred in a SCR of the world. The maximum *intensity* reached X (MSK scale). This is the second largest event in the western margin of peninsular India continental region, after the 1819 Kutch earthquake of M_W 7.8. The 2001 Bhuj earthquake is another example of a deeper SCR earthquake that occurred at a depth of 25 km in the Kutch Rift Basin. The fault-plane solution of the main shock and the aftershocks show complicated seismogenic structures. The observations suggest a *fault interaction model*, which illustrates that the main shock originated at the base of the paleo-rift basin by reverse faulting; the rupture propagated along NE as well as along NW. The aftershocks occurred by left-lateral strike-slip motion along the NE trending fault, compatible with the main shock solution, and by pure reverse to right-lateral strike-slip motion along the NW trending conjugate fault; these are not compatible with the main shock solution. *Seismic tomography* study revealed high V_p, low V_s and high V_p / V_s in the source area, which indicate that the source area is a fluid-filled fractured rock - matrix that triggered the main shock.

Key words: stable continental region, paleo-rift basin, aftershocks, strike slip, seismic tomography,

Self Introduction

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.

Stress field and non-double-couple aftershocks in the source area of the 2004 Mid-Niigata Prefecture earthquake in central Japan

Masahiro Kosuga[1], Satoshi Iwabuchi [2], Kazunori Murata [2]

1. Earthquake and Volcano Observatory, Graduate School of Science and Technology, Hirosaki University, Japan, mkos@cc.hirosaki-u.ac.jp
2. Faculty of Science and Technology, Hirosaki University, Japan

ABSTRACT

We have investigated focal mechanisms of aftershocks of the 2004 Mid-Niigata Prefecture (Niigata-Chuetsu), central Japan, earthquake (M = 6.8) by using P-wave polarity data obtained by a dense temporal seismic observation. The seismic network consisted of 145 temporary stations operated by the research team of aftershock observations for the earthquake. The purpose of this study is to understand the stress field in the source area that is characterized by quite complex fault system with two parallel, westerly dipping fault planes and one conjugate plane.

About two-thirds of well-constrained 565 focal mechanisms are reverse-fault type with WNW-ESE trending P-axes. Twelve events of normal-fault type are scattered mostly outside the major earthquake faults, suggesting the contribution of secondary resulting stress generated by major faulting. Minor strike-slip events are distributed in the northern and central part of aftershock zone. Stress tensors derived from the focal mechanisms exhibit the compressional stress field characterized by WNW-ESE trending horizontal maximum principal stress that is consistent with the regional stress field. The direction of both maximum and intermediate principal stress axes exhibits counterclockwise rotation as the area moves from north to south. The directional change of intermediate principle stress axis corresponds to the strike variation of fold axes in the area. The dip of maximum principal stress axes is nearly horizontal throughout the aftershock zone, but is locally inclined to the west around the hypocenter of mainshock. This variation occurs in the deeper part of mainshock fault that is thought to extend to the surface break in the southeastern part of aftershock zone. This local stress heterogeneity might be an indicator of stress accumulation in the deep part of fault.

We found that 9 aftershocks show non-double-couple (NDC) polarity distribution with significantly wide area of dilatational polarity on the focal sphere. We rechecked the waveform data and confirmed that the NDC events are caused neither by misread of polarities nor polarity reversal of specific stations. A marked feature of NDC earthquake is their concentration near the mainshock hypocenter. The location of NDC events are close to a zone of significant velocity change imaged by tomographic studies. However, because many ordinary double-couple (DC) earthquakes occurred in the same area, the velocity boundary cannot account for the occurrence of NDC events. The amplitude ratio of S- to P-waves for DC events takes an average value of 6.3, which is consistent with the theoretical expectation. On the other hand, the average ratio for NDC events takes a value of 4.9. Though the value for NDC events is slightly lower than that for DC events, the individual ratio for NDC events is in the extent of ratio distribution for DC events. Thus, we may ascribe the existence and movement of crustal fluids to the cause of NDC earthquakes, we cannot exclude the possibility of some DC sources such as simultaneous rupture of double events.

Key words: Niigata-Chuetsu earthquake, focal mechanisms, stress tensor, earthquake fault, non-double-couple.

PRESENTER'S BIOGRAPHY

Masahiro Kosuga is an Associate Professor of Graduate School of Science and Technology, Hirosaki University. He was born in Iwate Prefecture on July 20, 1955, and graduated from the Graduate School of Science, Tohoku University. He belongs to the Earthquake and Volcano Observatory that is an affiliated facility of School. He is a seismologist and his major jobs are the management and administration of Observatory, education to senior and graduate students, and his seismological research. The observatory operates 7 seismic stations and gathers data from about 160 stations covering a region from northern Tohoku to southern Hokkaido in northern Japan. His major research field includes seismicity and seismotectonics in the region, focal mechanisms of earthquakes including non-double-couple or low-frequency events, scattered wavefield by heterogeneities in the lithosphere. During three years until 2007, he served as the editor in chief of Zisin, the Journal of the Seismological Society of Japan.

Determination of a velocity model for use by the SANSN in earthquake location

V. Midzi, I. Saunders, M. B. C. Brandt, T. Molea

Council for Geoscience, Seismology Unit, 280 Pretoria Road, Silverton, Pretoria 0001, S.A.
Email: vmidzi@geoscience.org.za

ABSTRACT

Knowledge of the velocity model of an area is essential both for earthquake location and tectonic implication. Locating earthquakes using an unreliable model contributes in part to the uncertainties of active fault mapping and unexplained scatter of seismic locations. Given that we strive to continually improve our location abilities, it is necessary to always improve on the model used in the location process. The travel time inversion method was used to estimate a 1D velocity model that can be utilised by the South African National Seismic Network (SANSN) in seismic data analysis. The velocities obtained are approximately equal to the average velocity of the 3D structure within the same depth range that has been sampled by the data. Good quality data from 1300 earthquakes recorded by the SANSN were selected for the inversion process which was done using the program VELEST. Using two initial velocity models, the inversion process produced two final models from which one 'best' model was selected. To test the new model, a sample of well recorded data from the SANSN database was relocated and results compared to previous data analyses. The velocity model will continue to be improved with time as more seismic stations are installed in the country especially in the southern part and more data collected.

Keywords: Velocity model, travel time, location, earthquakes, South Africa

DR. VUNGANAI MIDZI

Dr V. Midzi is employed as a Scientific Officer in the Seismology Unit of the Council for Geoscience in Pretoria, South Africa. His qualifications include an MSc and PhD in Seismology from Bergen University, Norway. Dr Midzi is a well rounded seismologist with experience in seismic monitoring and seismic hazard analysis, which is his main field of work. He has worked on projects in seismic monitoring sponsored by IPPS under the East and Southern Africa Seismological Working Group of which he is an active member, as well as on other research and commercial seismic hazard studies on the African continent. His experience also includes work as an academic at the National University of Science and Technology, Zimbabwe. He has presented his research work at several conferences and workshops, and is well published in reputable journals.

Chuya (Altai) 27.09.2003 Intraplate Seismic Event: The Main Features Revealed by Combined Analysis of DInSAR, GPS, Seismology and Seismotectonics.

Mikhailov V.[1], Nazaryan A.[2], Kiseleva E.[2], Timoshkina E.[2], Diament M.[2], Shapiro N. [2],

1. Institute of physics of the Earth, RAS, Russia, mikh@ifz.ru
2. Institut de physique du Globe de Paris, France, diament@ipgp.jussieu.fr

ABSTRACT

Chuya (Altai) 27.09.2003 earthquake occurred in the broad belt of intraplate seismicity in front of India – Eurasia collision zone. Co-seismic displacement field in the area of this earthquake was investigated using ENVISAT ASAR images. A robust map of the satellite line-of-sight displacements was obtained for not forest-covered, flat-topography Chuya and Kurai depressions, i.e. a good correlation was obtained only for a part of the epicenter area. In such case, surface geology data on surface trace of the rupture, CMT solutions and regional GPS data (started here in 2000) on co-seismic displacements play an important role in data inversion. Position of ruptures corresponding to the main shock and three largest aftershocks (6.7, 6.6 and 6.2) which occurred during four consequent days was found in result of joint inversion of DInSAR and GPS data. The inversion was constrained by seismology and data on the surface trace of the rupture. We started with three-fault-planes model varying parameters of the planes and subdividing them into two, four etc parts until the solution stabilizes and changing non-linear parameters within assigned limits.

Our model fits well both interferometry and geodesy data, but differs from previous models in strike and dip of the ruptures as well as in magnitude and direction of the slip vectors. The main difference is in the rupture of the main shock and 6.7 aftershock. Joint inversion of InSAR and GPS data provides considerably bigger displacements at the fault planes in comparison to previous models. Estimated magnitudes (7.15 for the main shock and 6.8 – 6.9 for two main aftershocks) are very close to seismological estimates.

Key words: Chuya (Altai) earthquake, DInSAR-GPS joint inverion.

PRESENTER'S BIOGRAPHY

Valentin O. Mikhailov graduated in 1971 from Moscow State University. He received his PhD (1978) and Doctor of Sciences (1989) degrees in geophysics from the Schmidt Institute of Physics of the Earth Russian academy of Sciences (IPE RAS). He worked in Institute of Mechanics of Moscow State University. Since 1979 he is head of laboratory at IPE RAS and also professor of Lomonosov Moscow State University teaching "Geodynamics" and "Satellite geodesy and gravity" and visiting professor in Institut de physique du Globe de Paris (since 2000). His research interests include comprehensive interpretation of geophysical data, numerical geodynamical modeling of tectonic processes and structures, theory and methods of potential fields interpretation including satellite gravity.

Aftershock activity in the UK

RMW Musson[1], SL Sargeant[2], L Ottemöller[3]

1. BGS, UK, rmwm@bgs.ac.uk
2. BGS, UK, slsa@bgs.ac.uk
3. BGS, UK, lot@bgs.ac.uk

ABSTRACT

It has been observed in the last 40 years that the larger British earthquakes have shown strong contrasts in aftershock behaviour. Some have had extended sequences of aftershocks, others almost none at all. Examination of historical data confirms this, and shows that some locations tend to consistently produce strong aftershock activity while others consistently do not. In this study we examine the spatial distribution of those events that have had long aftershock sequences and attempt to relate the contrast between these and less prolific sequences to tectonic distinctions and characteristics of the earthquake rupture. If a binning strategy is applied, average number of aftershocks can be related to mainshock magnitude, even though this breaks down for individual events. From this relationship it can be computed that fractal dimension of seismogenic faulting in the UK is 1.48.

Key words: intraplate seismicity, aftershocks, UK

PRESENTER'S BIOGRAPHY

Roger Musson has worked with the British Geological Survey since 1980, and is Head of Seismic Hazard and Archives. He has worked extensively in the fields of seismic hazard, historical seismology and macroseismology.

Seismicity and Tectonics of Madagascar

J.M.S. Rakotomalala[1], **H.N.T. Razafindrakoto[2],** G. Rambolamanana[3],
D. Rakotomanana[4]

1. Institute and Observatory of Geophysics in Antananarivo, BP 3843, 101-Antananarivo, Madagascar, rakotomalalamireille@yahoo.fr
2. Institute and Observatory of Geophysics in Antananarivo, BP 3843, 101-Antananarivo, Madagascar, htendri@yahoo.fr
3. Institute and Observatory of Geophysics in Antananarivo, BP 3843, 101-Antananarivo, Madagascar, rambolamanana_gerard@yahoo.fr
4. PGRM/Polytechnic School of Antananarivo, 101- Antananarivo, Madagascar, rakdomi@yahoo.fr

ABSTRACT

The aim of this study is to define the seismogenic zones and to provide a vast knowledge on the seismotectonics of Madagascar. Many researchers have been working on the seismicity of Madagascar (Rakotondraibe, 1977; Fourno, 1990; Bertil, 1998; Rambolamanana (1999)) but data from few stations has been used. Few years ago, Madagascar's seismic network was extended and new data from new stations became available. In this study, which is complementing previous records, new datasets have been used in order to enhance the seismotectonics of Madagascar. For this purpose, a total of 10 369 events have been analyzed and have enabled us to build the seismicity map of Madagascar. These data are stored in the database of the Observatory of Antananarivo recorded from 1975 until 2007. This map shows 29 seismogenic zones, 13 of them match with the result obtained by Rakotondraibe, 1977. Besides, seismic alignments have been drawn according to the distribution of the event and the geology of the zones. For interpretation, the Madagascar tectonometamorphic units map (Collins 2002) and Landsat ETM 7 images taken between 1999 and 2000 have been used. In general, an agreement is observed between the tectonometamorphic units, the features from the landsat and the seismic alignment.

Key words: Madagascar, seismicity, tectonics, seismogenic zones

PRESENTER'S BIOGRAPHY

Razafindrakoto Hoby is a PhD student at the University of Antananarivo. Her topic consists of the seismic hazard analysis. Her research over the last 3 years focused on the seismic zoning and near source effect. This year, she was involved in another project, "Risk Management in Valparaiso", with ENEA as Main Coordinator and ICTP as a partner. She got her second year's doctorate program in seismology in 2003, and from then, she started her research work. She attended in 2004, the International Training Course on: "Seismology, Seismic Data Analysis, Hazard Assessment and Risk Mitigation" of the GFZ and she is currently a junior associate at the Abdus Salam International Centre for Theoretical Physics, Trieste, Italy

A comparison of two recent damaging earthquakes in the UK.

Susanne Sargeant[1], Lars Ottemöller[1], Brian Baptie[1]

1. British Geological Survey, United Kingdom, bbap@bgs.ac.uk

ABSTRACT

We compare two damaging moderate size British earthquakes. The first occurred near the town of Folkestone on the southeast coast of England on 28 April 2007 with a moment magnitude of 3.8 (4.2 ML). The earthquake was shallow at about 5 km. The event caused considerable damage near the epicenter and was felt throughout south-eastern England. The second earthquake was slightly larger with a moment magnitude of 4.4 (5.2 ML) and occurred on 27 February 2008 in Lincolnshire (eastern central England). Incidences of damage were sporadic but observed over a relatively wide area and the earthquake was felt over much of the UK. This earthquake was a lot deeper at about 20-25 km. Depths are constrained using array data recorded at teleseismic distances. For both earthquakes we are able to invert for the moment tensor using regional broadband data. Both mechanisms are predominantly strike-slip and consistent with the regional stress pattern. We compare the aftershock sequences, source parameters, ground motion observations and distribution of intensity. We determine stress drop and rupture dimensions for each event by modelling the source displacement spectra. We correct for attenuation using a new regional average $Q_{Lg}(f)$ model for the British Isles. We find that the deeper earthquake is characterized by a significantly higher stress drop. This corresponds to a larger slip relative to the shallower earthquake, while the fault area is about the same for the two events. We use the source parameters and $Q_{Lg}(f)$ model to compute peak ground acceleration for both earthquakes using the stochastic method. We are able to reproduce the ground motions from the shallower event with this model but for the deeper event, the modelled ground motions are almost a factor of ten lower than observed. This unexpectedly high ground motion does not seem to be caused by local site effects.

Key words: Intraplate earthquakes, moment tensor, stress drop, peak ground acceleration.

PRESENTER'S BIOGRAPHY

Brian Baptie is a member of the British Geological Survey Earthquake Seismology team working mainly on improving understanding of natural seismic activity in the UK and offshore areas. Areas of research interest include seismo-tectonics and stress regimes controlling UK seismicity and using passive seismicity to image crustal and upper mantle structure under the UK. Recent research has focused on the use cross-correlation of seismic noise at newly installed broadband stations to image spatial variation in seismic velocity under the UK.

Thinned crust-oblique slip faults and mechanism of intraplate volcanic lake seismicity: The Lake Van basin, Eastern Anatolia Accretionary Complex (EAAC), E-Turkey

Mustafa Toker[1], Sebastian Krastel[2], Filiz Demirel-Schlueter[3], Emin Demirbag[4], and Caner Imren[5]

1. Istanbul Technical University, Eurasia Institute of Earth Sciences, Istanbul-Turkey, tokermu@itu.edu.tr
2. Christian-Albrechts University, Leibniz Institute of Marine Sciences (IFM-GEOMAR), Kiel-Germany, skrastel@ifm-geomar.de
3. Bremen University, Department of Geosciences, Bremen-Germany,
4. Istanbul Technical University, Department of Geophysical Engineering, Istanbul-Turkey, demirbag@itu.edu.tr
5. Istanbul Technical University, Department of Geophysical Engineering, Istanbul-Turkey, imren@itu.edu.tr

ABSTRACT

The Lake Van basin surrounded by a Quaternary volcanic chain is a volcano-tectonic product of mélange wedge-controlled basement processes. This lake is also obliquely-faulted sedimentary block that moves and elongates the crust perpendicularly to the direction of shortening. Oblique-slip faults can be considered as the boundaries of upper crustal blocks (“flakes”) moving over a detachment surface located at the brittle-ductile transition. This consideration has important implications for lake seismicity and implies that the majority of earthquakes are restricted to the upper part of the crust (less than 10 km depth). Seismic reflection data and structural interpretation confirmed that the lake has a key role of the weaker-buoyant rhombohedral block-wedge tectonism and magmatic intrusions along the fault planes. This means that the lake is “oblique crustal flake” of the irresistant Mesozoic accretionary material (e.g., squashed mélange wedge). This flake structure suggests two basic types of seismogenic sources; *seismic zones* (volcano/tectono-magmatic events-and/or-tectono-thermal seismogenesis) and *major active boundary faults* (valuable vertical offsets) in the Lake. This study aims to present a methodological and conceptual approach to effectively analyze the faulting/deformation styles and seismicity relationships and to present new insights into the earthquake based-tectonic framework of the lake. We try to understand physical mechanisms of upper crust-seated oblique-slip faults and aseismic slips on the possible downward extensions of these faults. We search for the stress-strain state of seismicity in lake that is a style of intraplate volcanic seismicity. Circum-lake seismicity is reconsidered by a comparative analysis of multi-channel seismic reflection data and spectral analysis of three-component seismograms.

Geophysical data analysis and structural interpretation suggested a model that highlights intraplate volcanic seismicity by aseismic slip acceleration of oblique-slip boundary faults. This model assumes that there are two end-member models of the process by which intraplate earthquakes are generated, “regional and local stress models”. Intraplate volcanic seismicity suggests that, in “local stress model”, concentrations of local stress generate intraplate earthquakes. This model argues “low-strength model”. In this model, stress accumulates in the upper brittle crust above the regions of low viscosity-high temperature in the crust-asthenosphere contact. Thus, strains accumulate by inhomogeneity of the ductile flow in the lower crust under basal drag and far-field convergent boundary conditions. The spatial distribution of low viscosity is confined to a localized ductile fault zone. The shallow (7-9 km) concentration of the smaller-moderate earthquakes (*Md*, 3-4), high seismic b-values (0.99-1), tremor/long-term period/hybrid events and magmatic intrusive activity along the extensional/transtensional fault planes clearly show localized stress accumulation, strain condensation, aseismic creep and stress releasing along the ductile shear zone beneath the lake. It is argued that the Lake Van is characterized by low shear strength and buoyancy. To determine the most plausible physical model for oblique faults in the lake, we propose “local stress model” in which there are two possibilities: the first is called “low strength model-distributed shear”, and the second is called “low strength model-localized shear”. We suggest that the “low strength-localized shear model” is the most plausible mechanism, because seismogenic faults of intraplate earthquakes have downward extensions in the lower crust.

In the Lake Van basin, the thinned crust is at the direct contact to asthenosphere (no mantle lid) and the lower crust is rheologically weaker, irresistant and buoyant. Downward extensions of oblique-slip faults are most probably smaller than 10 km crustal flake thickness (elastic lid). Aseismic slips on the downward extensions accumulate stress on the faults, which is frequently released. Thus, “local stress model” indicates that lower crust with low shear strength concentrates local stress accumulation within the upper crust beneath the faults and the lake-wedge. Seismogram data and faulting-deformation map indicate that upper crustal-oblique deformation drives the present-day seismicity of the lake and a possibility that the aseismic slips actually occurred on the downward extensions of the faults and accelerated before the large intraplate earthquakes in and around the lake. We conclude that the “low strength-localized shear model” including the acceleration of aseismic slips can explain various phenomena related to thin crustal deformation and intraplate volcanic lake seismicity.

Key words: oblique crustal flake, seismogenic sources, intraplate volcanic seismicity, low shear strength, spectral analysis, aseismic slip acceleration.

MUSTAFA TOKER

- Bacholar degree by Geophysical Engineering department, Yıldız Technical University, Istanbul-Turkey.
- Master degree by Department of Marine Geology and Geophysics, Institute of Marine Sciences, Middle East Technical University, Mersin-Turkey.
- Phd education in Earth System Science, Department of Marine and Climate Sciences, Eurasia Institute of Earth Sciences, Istanbul Technical University, Istanbul-Turkey.
- Research topics; Orogenesis-Collisional Geodynamics, Seismotectonics, Tectonics, Volcano-tectonics, Tectonic and Kinematic modeling, Salt-sediment dynamics, Halokinesis, Basin and delta analysis, Seismic sequence stratigraphy, Continental drilling process and Seismic/seismologic data interpretation.
- Studied areas; the NE-Mediterranean basin, the NW marginal province of the N-Cyprus platform, Eastern Anatolia Contractional Province (E-Turkey) and the N-delta province of the Black Sea.

Study on the Bunka-Kanagawa Earthquake of December 7, 1812

Yoshinobu Tsuji
Earthquake Research Institute, University of Tokyo, Japan,
tsuji@eri.u-tokyo.ac.jp

ABSTRACT

It is well known that the metropolitan area of Japan hit by two inter-plate earthquakes in the recent 400 years; one is the 1703 Genroku earthquake and the other is the 1923 Great Kanto earthquake. In addition that an intra-plate earthquake, called Ansei-Yedo Earthquake occurred in 1855 and nearly ten thousand people were killed in the city zone of Yedo, Tokyo at present, and in its vicinities. In the recent twenty years a large amount of historical documents describing historical earthquakes were found out in Japan, and it is become cleared that an eminent large earthquake took place in the eastern part of Kanagawa Prefecture on December 7, 1812 (October 4th of the 9th year of Bunka period in the Japanese calendar). The greater parts of houses of in three post towns of the Tokaido highway, Kanagawa, Hodogaya, and Totsuka which are in the Yokohama city zone at present were entirely destroyed due to the strong shaking. In the most part of Yedo(Tokyo) city zone felt seismic intensity 5, and houses were partially damaged. The radiuses of the areas of the seismic intensities 4, 5, and 6 in JMA scale are estimated at 65km, 35km, and 15 km respectively, by which we can estimate that this earthquake has the magnitude of about M = 6.8.

Key words: historical earthquake, earthquake in the metropolitan area, the 1812 Bunka Kanagawa earthquake, intra-plate earthquake

PRESENTER'S BIOGRAPHY

Born in 1947 at Nara, Japan

Graduated from the Civil Engineering course, Faculty of Engineering, University of Tokyo in 1969

Finished the master course of the geophysical division, faculty of sciences, University of Tokyo in 1971

Obtained the title of PhD. at the University of Tokyo in 1982.

Researcher of the National Research Institute for Disaster Prevention in the period 1972 to 1986.

Associate professor of Earthquake Research Institute, University of Tokyo from 1986 till now.

Spatial heterogeneity of the structure and seismic activity in Hyuga-nada region, southwest Japan

Kenji Uehira[1], Hiroshi Yakiwara[2], Tomoaki Yamada[3], Kodo Umakoshi[4], Shigeru Nakao[5], Reiji Kobayashi[5], Kazuhiko Goto[2], Hiroki Miyamachi[5], Kimihiro Mochizuki[3], Kazuo Nakahigashi[3], Masanao Shinohara[3], Toshihiko Kanazawa[3], Ryota Hino[6], Masaji Goda[7], Hiroshi Shimizu[1]

1. Institute of Seismology and Volcanology, Kyushu University, Japan
2. Nansei-toko Observatory for Earthquakes and Volcanoes, Kagoshima University, Japan
3. Earthquake Research Institute, University of Tokyo, Japan
4. Faculty of Environmental Studies, Nagasaki University, Japan
5. Faculty of Sciences, Kagoshima University, Japan
6. Research Center for Prediction of Earthquakes and Volcanic Eruptions, Tohoku University, Japan
7. Faculty Fisheries, Nagasaki University, Japan

ABSTRACT

In Hyuga-nada region, big earthquakes (M7 class) have occurred at intervals of about dozens of years, and so plate coupling varies dozens of kilometers specially. Big earthquakes (M7 class) have occurred in the north region from latitude 31.6 degrees north, but it has not occurred in the south region from latitude 31.6 degrees north. And microseismicity varies spatially. It is important to understand seismic activity, stress field, and structure in such region in order to understand seismic cycle.

We performed extraordinary seismic observation for 75 days from April to July 2006. 23 pop-up type OBSs were deployed above hypocentral region of Hyuga-nada using Nagasaki-maru and three data loggers were deployed in order to compensate a regular seismic network on land.

We detected earthquakes more than 2 times of JMA. Seismic activity in source region of the 1961 Hyuga-nada Earthquake (M7.0) is low, but around its source region, seismic activity is very high. In order to obtain a 3D seismic velocity structure and precise hypocenter distribution around the Hyuga-nada region, we used Double-Difference (DD) Tomography method developed by Zhang and Thurber (2003). We could detect the structure of subduction of Kyushu-Palau Ridge at low seismicity area. So, the subducted Kyushu-Palau Ridge may cause the strong interplate coupling.

Key words: seismicity, velocity structure, Hyuga-nada, OBS.

PRESENTER'S BIOGRAPHY

Kenji UEHIRA (uehira@sevo.kyushu-u.ac.jp)
1998 - : Research Associate of Kyushu University
Doctor of Science.