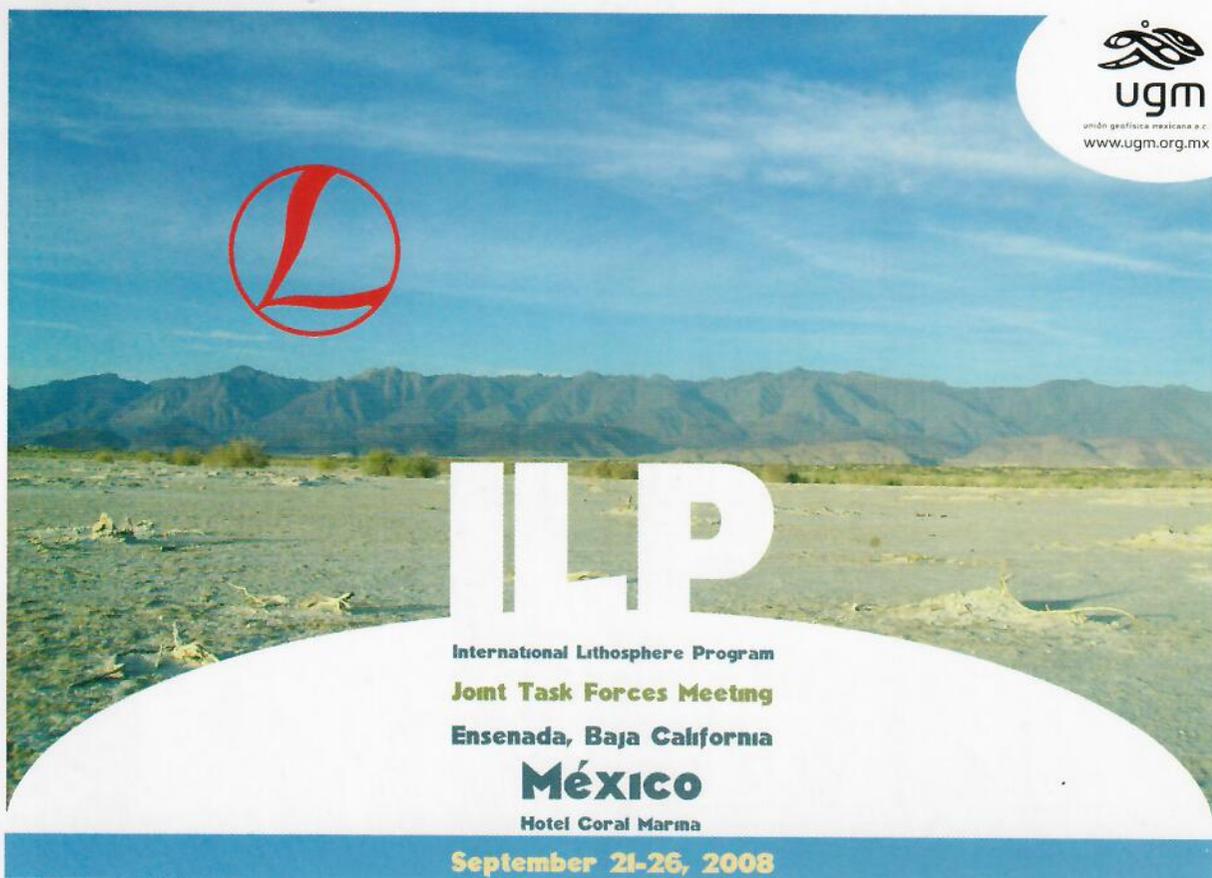


Unión Geofísica Mexicana, A.C.

geos



ILP
International Lithosphere Program
Joint Task Forces Meeting
Ensenada, Baja California
México
Hotel Coral Marma
September 21-26, 2008

Volumen 28

No. 1

Septiembre de 2008

GEOS

<http://www.ugm.org.mx/geos.html>

**BOLETÍN INFORMATIVO
DE LA
UNIÓN GEOFÍSICA MEXICANA, A.C.**

GEOS se publica tres veces al año patrocinada por el Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE) y editada conjuntamente por la UGM y el CICESE.

UNIÓN GEOFÍSICA MEXICANA, A.C.
Mesa Directiva 2008-2009

Dr. Julián Adem Chain
Presidente Honorario

Dr. Oscar Campos Enríquez
Presidente

Dr. José Manuel Romo Jones
Vicepresidente

Dr. Xyoli Pérez Campos
Secretario General

Dr. Víctor Manuel Wong Ortega
Tesorero

Dr. Avto Gogichaisvili
Secretario de Investigación

Dr. Ramón Zúñiga Dávila
Secretario de Difusión

Dr. Héctor López Loera
Secretario de Educación

Editores Principales

Luis A. Delgado Argote
ldelgado@cicese.mx
CICESE

Ramón Zúñiga Dávila
ramon@geociencias.unam.mx
Centro de Geociencias, UNAM

Comité Editorial

Harald Böhnelt, Instituto de Geofísica, UNAM
Noel Carbajal Pérez, IPICYT
Oscar Campos, Instituto de Geofísica, UNAM
Gerardo Carrasco, Instituto de Geología, UNAM
Ana Luisa Carreño, Instituto de Geología, UNAM
Carlos Flores Luna, División de Ciencias de la Tierra, CICESE
José Luis Frías Salazar, INEGI
Juan García Abdeslem, División de Ciencias de la Tierra, CICESE
René Garduño, Centro de Ciencias de la Atmósfera, UNAM
Manuel Grajales N., Instituto Mexicano del Petróleo
Margarita López Martínez, División de Ciencias de la Tierra, CICESE
Alejandro Hinojosa Corona, División de Ciencias de la Tierra, CICESE
Miguel Lavín Peregrina, División de Oceanología, CICESE
Luis Munguía Orozco, División de Ciencias de la Tierra, CICESE
Jorge Ledesma Vázquez, Facultad de Ciencias Marinas, UABC
Guillermo Pérez, PEMEX
Domitilo Pereyra, Universidad Veracruzana
Francisco José Sánchez Sesma, UNAM
Miguel Téllez, UABC
Gustavo Tolson, Instituto de Geología, UNAM
Carlos Suárez Plascencia, Universidad de Guadalajara
Héctor Pérez de Tejada, Instituto de Geofísica, UNAM

Apoyo Técnico Editorial

Daniel Peralta - dperalta@cicese.mx
Gustavo Peinemann Le Duc - peineman@cicese.mx
María Cristina Álvarez Astorga
Alejandro F. Nava Pichardo

GEOS, boletín informativo de la Unión Geofísica Mexicana, contiene artículos de investigación originales, así como artículos de divulgación y notas cortas y sobre aspectos relevantes para la difusión de la actividad científica, tecnológica y docente en las ciencias de la Tierra, así como noticias de interés para los miembros de la UGM. Las instrucciones para los autores se encuentran al final de cada revista y en <http://www.ugm.org.mx/geos.html>

Correspondencia a:
Editorial GEOS

División de Ciencias de la Tierra, CICESE
Km 107, Carret. Tijuana-Ensenada
Ensenada, B.C., México
Tel.: (646)175-0500, Ext. 26060

Título: **GEOS**

Periodicidad: cuatrimestral

ISSN: 0186-1891

Editado en la División de Ciencias de la Tierra, CICESE, Km 107, Carret. Tijuana-Ensenada, Ensenada, 22860, B.C., México.

Index

	Page
Editorial GEOS	5
ILP Editorial	7
Program	9
ILP Introduction - Founding partner of International Year of Planet Earth: Frontiers in integrated solid Earth sciences	13
<small>Cloetingh S.A.P.L. y Negendank J.F.W.</small>	

Sessions

1. Basin processes	15
2. Gulf of California and NW Mexico	19
3. Gulf of Mexico and its surroundings	23
4. HC resources	27
5. Poster session 1	31
6. Volcano failure	35
7. Volcanism and geodynamics	39
8. Lithosphere-asthenosphere interactions, baby plumes and paleostress	43
9. Poster session 2	47
10. Basin processes and case studies	51
Author index	55
Field Trip Log - Gulf of California Rift System: Laguna Salada-Valles Chico-San Felipe, Baja California, México	57
<small>Francisco Suárez-Vidal</small>	

Editorial GEOS

Reunión del International Lithosphere Program en México

Hace dos años el presidente del ILP, Sierd Cloetingh visitó México y sugirió que una de las reuniones de los grupos de trabajo se efectuara en este país. Con esta iniciativa se amplía el cubrimiento de los objetivos del ILP que contemplan, entre otros, la promoción de proyectos internacionales a través de reuniones entre expertos. La ubicación geográfica y la oportunidad de visitar el sistema San Andrés-Golfo de California motivó que la reunión se realizara en Ensenada, B.C., por lo que se buscó el apoyo logístico del CICESE y se solicitó la promoción y apoyo editorial de la Unión Geofísica Mexicana. La UGM ofreció así sus medios de difusión, página web y GEOS, para hacer promoción y publicar los resúmenes de la reunión, respectivamente.

La reunión es pequeña pues se presentarán 47 trabajos distribuidos en 10 sesiones, entre las cuales, las de los temas de cuencas y volcanismo son las que concentran la mayor cantidad de trabajos. Destaca el hecho de que están representadas 49 instituciones de educación superior (IES) o del sector productivo de 21 países distintos (14 europeos, 4 americanos y 3 asiáticos), según puede observarse en la tabla de instituciones participantes adjunta. Tanto los organizadores, como los anfitriones, esperamos que esta reunión no solamente sea académicamente rica, sino que logre el objetivo principal de promover el inicio de proyectos de colaboración internacional y de carácter multidisciplinario.

Instituciones Participantes

	Institución	Departamento o dependencia	País
1.	AREVA		USA
2.	Ben Gurion University of the Negev		Israel
3.	Canadian Natural Resources Ltd.		Canada
4.	Chevron Norge AS, Oslo, Norway		Norway
5.	CICESE	Departamento de Geología	México
6.	CICESE	División de Ciencias de la Tierra	México
7.	Collège de France, Aix-en Provence		France
8.	Copenhagen University		Denmark
9.	ENTRIX, Inc.		USA
10.	GeoForschungsZentrum		Germany
11.	Geological Survey of Canada		Canada
12.	Geological Survey of Norway		Norway
13.	Hungarian Academy of Sciences	Institute of Nuclear Research	Hungary
14.	Institut de Physique du Globe de Paris		France
15.	Institut Français du Pétrole		France
16.	Institut National de la Recherche Scientifique	Eau, Terre et Environnement	Canada
17.	Institute of Geology	Key Laboratory for Continental Dynamics	China
18.	Institute of Physics of the Earth		Russia
19.	Instituto Francés del Petróleo		France
20.	Instituto Mexicano del Petróleo		México
21.	Katholieke Universiteit Leuven		Belgium
22.	Museum National d'Histoire Naturelle		France
23.	Netherlands Organisation for Applied Scientific Research (TNO)		Netherlands
24.	PEMEX	Exploración y Producción	México
25.	PEMEX	Coordinación de Plays Zona Norte	México
26.	Petróleos de Venezuela, S.A.		Venezuela
27.	Philippine National Oil Company	Energy Development Corporation	Philippines
28.	Romanian Academy	Institute of Geodynamics	Romania
29.	Sapientia University	Dept. of Environmental Sciences	Romania
30.	School of Earth and Environment		United Kingdom
31.	Scripps Institution of Oceanography		USA
32.	SHELL		
33.	Smithsonian Institution		USA
34.	SUNY University at Buffalo		USA
35.	UANL	Facultad de Ciencias de la Tierra	México

36.	UNAM	Centro de Geociencias	México
37.	UNAM	Facultad de Ingeniería	México
38.	UNAM	Instituto de Geología	México
39.	United States Geological Survey		USA
40.	Università degli Studi dell'Insubria	Dipartimento di Scienze Chimiche e Ambientali	Italy
41.	Università degli Studi di Milano Bicocca	Dipartimento di Scienze Geologiche e Geotecnologie	Italy
42.	Université Pierre et Marie Curie, Paris		France
43.	University of Arizona	Dept. of Geosciences	USA
44.	University of Athens	Department for Dynamic Tectonic and Applied Geology	Greece
45.	University of Basel	Institute for Geology and Paleontology	Switzerland
46.	University of California at Riverside		USA
47.	University of Copenhagen	Department of Geography and Geology	Denmark
48.	University of Oslo	Department of Geosciences	Norway
49.	University of Portsmouth		United Kingdom
50.	University of the Philippines	National Institute of Geological Sciences	Philippines
51.	Uppsala University	Department of Earth Sciences	Sweden
52.	Vlaamse Instelling voor Technologisch Onderzoek		Belgium
53.	Volcanic Basin Petroleum Research		Norway
54.	Vrije Universiteit Amsterdam	Department of Petrology	Netherlands
55.	VU University Amsterdam	Faculty of Earth and Life Sciences	Netherlands

ILP Editorial

International Lithosphere Program Task Forces Meeting

The basic objectives of the ILP Task Forces are:

1. to assist the international community of Earth Scientists involved in the study of asthenospheric and deep lithospheric/crustal processes to exchange views with colleagues involved in similar studies, and to promote collaborative projects integrating surface and deep processes for regional case studies;
2. to promote regular meetings involving colleagues from universities, research institutes as well as the industry;
3. to provide support for young scientists (PhD and post-docs) to participate in the activities of this international network.

The most efficient way to secure such interactions between the participating teams and industry is to meet once a year during a dedicated seminar of individual Task Forces, tentatively including 3 days of indoor presentations (single session with 80-120 participants, i.e. Hedberg-type format), linked with a 2-days field-trip.

Because of IUGS/IUGG commitments and global significance of ILP Task Forces, former meetings of the Task Force on Sedimentary Basins have been held successively in Europe (Thrust belts and foreland basins, Paris, France, 2005), North America (Circum-Polar Basins, Québec, Canada, 2006), and Africa (Vertical movements in African Basins and Margins, Marrakech, Morocco, 2007).

Following the successful meetings of the ILP Task Force on Sedimentary Basins, CICESE (Center of Scientific Research and Graduate Studies in Ensenada) and the Mexican Geophysical Union (Unión Geofísica Mexicana, UGM) are hosting this 2008 workshop in Ensenada, Baja California, Mexico, from September 21 to 26, involving also the other ILP Task Forces dealing with mantle processes, volcanism and paleostress.

It is intended that these ILP meetings will address general topics especially relevant for the area where the meeting takes place, and provide also a forum of discussion for participants from the various disciplines involved in Lithosphere studies. Therefore, the field trip organized for this 2008 ILP meeting will provide specific insights on the Gulf of California rift system.

Participants to the Ensenada meeting of the Task Force will be informed on site on the dead lines and guidelines for submitting a manuscript for the Proceedings volume.

We kindly acknowledge the sponsorship of ILP and

Reunión de los Grupos de Trabajo del International Lithosphere Program

Los objetivos principales de los Grupos de Trabajo del International Lithosphere Program (ILP) son:

1. Ayudar a la comunidad geocientífica internacional involucrada en el estudio de los procesos astenosféricos, así como litosféricos y de corteza profundos a intercambiar puntos de vista; a promover proyectos de colaboración que integren procesos profundos y superficiales para identificar casos de estudio regionales;
2. promover reuniones periódicas en las que participen colegas de universidades, de instituciones de investigación y de la industria;
3. apoyar a los científicos jóvenes (doctorantes y postdoctorantes) para que participen en las actividades de esta red internacional.

La forma más eficiente para asegurar las interacciones entre grupos participantes y la industria es a través de reuniones anuales en grupos de trabajo individuales, en las que, tentativamente, se efectúen presentaciones presenciales con 80 a 120 participantes y excursiones de campo de un par de días.

Debido a los compromisos IUGS/IUGG y al significado global de los Grupos de Trabajo del ILP, las reuniones anteriores del Grupo de Trabajo sobre Cuencas Sedimentarias se han efectuado, sucesivamente, en Europa (Thrust belts and foreland basins, Paris, France, 2005), Norteamérica (Circum-Polar Basins, Quebec, Canadá, 2006) y África (Vertical movements in African Basins and Margins, Marrakech, Marruecos, 2007).

Siguiendo a las exitosas reuniones del Grupo de Trabajo sobre Cuencas Sedimentarias, el CICESE y la Unión Geofísica Mexicana son anfitriones del Taller 2008 en Ensenada, Baja California, involucrando a los grupos de trabajo que tratan sobre procesos del manto, volcanismo y paleoesfuerzos.

Se intenta que las reuniones del ILP traten temas generales que sean especialmente relevantes para el área donde se efectúa la reunión y ofrecer un foro de discusión para los participantes de las distintas disciplinas relacionadas con estudios de la Litósfera. Por ello, la excursión organizada para esta reunión 2008 del ILP ofrecerá información relevante acerca del sistema de rift del Golfo de California.

Los participantes a la reunión en Ensenada recibirán información durante la reunión acerca de la forma y fechas para enviar manuscritos para el volumen del evento.

Schlumberger, as well as the very strong involvement of CICESE and UGM, who are hosting this 2008 Joint ILP Task Forces meeting in Ensenada. Thanks a lot also to Luis, Felipe, Ivonne Pedrín, Daniel Peralta, and other Mexican colleagues for their enthusiasm and efficiency in coordinating this event.

François Roure and Leni Scheck-Wenderoth, on behalf of the ILP Task Force 6, Sierd Cloetingh and Jörg Negendank, on behalf of ILP, Alessandro Tibaldi and Larissa Dobrzhinetskaya, on behalf of the ILP Task Forces 2 and 4.

François Roure and Leni Scheck-Wenderoth, a nombre del Grupo de Trabajo 6; Alessandro Tibaldi y Larissa Dobrzhinetskaya, a nombre del Grupo de Trabajo 2 y 4; Sierd Cloetingh and Jörg Negendank, a nombre del ILP, agradecen el patrocinio de Schlumberger así como el intenso trabajo de apoyo del CICESE y coordinación de la UGM para efectuar esta Reunión 2008 de los Grupos de Trabajo del Internacional Lithosphere Program en Ensenada. Muchas gracias también a Ivonne Pedrín, Daniel Peralta, Luis, Felipe, y otros colegas mexicanos por su entusiasmo y eficiencia en la coordinación de este evento.

Program

Day	Time	Presentation title	Authors	First author institution
Mon 22		Field trip Gulf of California Rift System: Laguna Salada – San Felipe, Baja California		
Tue 23		Field trip Gulf of California Rift System: Laguna Salada – San Felipe, Baja California		
Wed 24	9:00 – 9:10	Welcome address by Federico Graef (Director of CICESE), Luis Delgado (CICESE) and Felipe Ortuño (IMP)	Graef Federico, Delgado Luis, Ortuño Felipe	CICESE, México
Wed 24	9:10 – 9:40	ILP Introduction - Founding partner of International Year of Planet Earth: Frontiers in integrated solid Earth sciences	Cloetingh S.A.P.L. y Negendank J.F.W.	Vrije Universiteit, Netherlands
		Session 1: Basin processes Chairs: Noëlle Schoelkopf and Patrick Unternehr		
Wed 24	9:40 – 10:00	S01-1 NEW ASPECTS OF MAGMATISM IN RIFTING AND BASIN FORMATION	Thybo Hans	University of Copenhagen, Denmark
Wed 24	10:00 – 10:20	S01-2 STRUCTURAL AND THERMAL MODELLING OF THE FORELAND BASIN OF CHIAPAS-TABASCO, MÉXICO	Ortuño Arzate Felipe y Sassi William	Instituto Mexicano del Petróleo, México
Wed 24	10:20 – 10:40	S01-3 3D STRUCTURE OF THE ORANGE BASIN, SOUTHWEST AFRICAN CONTINENTAL MARGIN	Hirsch K.K., Scheck-Wenderoth M., Bauer K., van Wees J. D., Cloetingh S.A.P.L. y Beekman F.	GeoForschungsZentrum Potsdam, Germany
		Coffee break		
		Session 2: Gulf of California and NW Mexico Chairs: Walter Mooney and Arturo Martín-Barajas		
Wed 24	11:10 – 11:40	S02-1 NEOGENE EVOLUTION OF RIFTING IN THE NORTHERN GULF OF CALIFORNIA: TECTONOSTRATIGRAPHIC ANALYSIS OF SEISMIC REFLECTION AND BOREHOLE DATA	Martín Arturo, Helenes Javier, González Escobar Mario, García Juan, Aragón Manuel, Carreño Ana Luisa y Pacheco Martín	División de Ciencias de la Tierra, CICESE, México
Wed 24	11:40 – 12:00	S02-2 AN ARC-COLLISION ZONE IN NORTHERN BAJA CALIFORNIA, MÉXICO, DETECTED FROM MAGNETOTELLURIC DATA	Pamplona Uriel y Romo Jones José Manuel	División de Ciencias de la Tierra, CICESE, México
Wed 24	12:00 – 12:20	S02-3 SEISMIC REFLECTION IMAGES OF THE WESTERN FARALLON BASIN, SOUTHERN GULF OF CALIFORNIA, MÉXICO	Piñero Lajas Doris, González Fernández Antonio, López Martínez Margarita, Lonsdale Peter y Kluesner Pared	División de Ciencias de la Tierra, CICESE, México
		Lunch		
		Session 3: Gulf of Mexico and its surroundings Chairs: Fernando Sánchez-Ferrer and Gary Gray		
Wed 24	14:00 – 14:30	S03-1 TECTÓNICA GRAVITACIONAL Y MOVIMIENTOS CORTICALES CENOZOICOS EN LA MARGEN OCCIDENTAL DEL GOLFO DE MÉXICO	Martínez Reyes Juventino, Rangin Claude, Le Pichon Xavier, Andréani Louis, Le Roy Charlotte, Aranda García Mario, Flotté Nicolas y Husson Laurent	Centro de Geociencias, UNAM, México
Wed 24	14:30 – 14:50	S03-2 COB DEEP STRUCTURE IN A SHEAR MARGIN (WESTERN MAIN TRANSFORM - OFFSHORE VERACRUZ, SOUTHERN GULF OF MÉXICO)	Román Ramos Juan Rogelio, Sánchez Ferrer Fernando, Biegert Ed, Cruz Mercado Miguel Angel, Bartsch Erik, Salomon Mora Luis Enrique y Rosas Lara Carlos	PEMEX Exploración y Producción, México
Wed 24	14:50 – 15:10	S03-3 RECONSTRUCTION OF THE DEFORMATION AND FLUID FLOW HISTORY IN THE CÓRDOBA PLATFORM AND VERACRUZ BASIN (MÉXICO): VALIDATION AND CALIBRATION OF A BASIN MODEL	Ferket Helga, Swennen Rudy, Ortuño Arzate Salvador, Guilhaumou Nicole y Roure François	Vlaamse Instelling voor Technologisch Onderzoek, Belgium
Wed 24	15:10 – 15:30	S03-4 MODELADO DE FLUIDOS Y MIGRACIÓN DE HIDROCARBUROS EN UNA SECCIÓN DE LA REGIÓN PETROLERA DE VERACRUZ	González Mercado Esmeralda y Roure Francois	Petróleos Mexicanos, México
Wed 24	15:30 – 15:50	S03-5 PREDICCIÓN DE LITOFACIES EN AGUAS PROFUNDAS EN UN MARCO TECTÓNICO SEDIMENTARIO	Alzaga Ruiz Humberto, Granjeon Didier y Roure Francois	Instituto Mexicano del Petróleo, México
		Coffee break		

Session 4: HC resources Chairs: François Roure and Felipe Ortuño				
Wed 24	16:30 – 17:00	S04-1 PROGRESS IN EXPLORATION: MAIN EXPLORATION BREAKTHROUGH AND EXPLORATION RESULTS FROM SOME FOLD BELTS PETROLEUM REGIONS	Mathieu Yves	Institut Français du Pétrole, France
Wed 24	17:00 – 17:20	S04-2 THE EFFECTS OF TECTONIC HISTORY AND FRAMEWORK ON PETROLEUM SYSTEMS AND RESOURCES IN EAGLE PLAIN BASIN AND ENVIRONS, YUKON TERRITORY, CANADA	Osadetz Kirk, Lane Larry, Chen Zhuoheng y Bird Timothy	Geological Survey of Canada, Canada
Wed 24	17:20 – 17:40	S04-3 A NEW THERMAL MATURATION MAP OF THE SILURIAN-DEVONIAN GASPÉ BELT BASIN IN THE QUÉBEC APPALACHIANS	Roy S., Bertrand R. y Malo M.	Institut National de la Recherche Scientifique, Canada
Session 5: Poster session 1				
Wed 24	17:40 – 18:40	S05-1 POSTER STRUCTURE AND STRATIGRAPHY IN THE WAGNER AND CONSAG BASINS, GULF OF CALIFORNIA, FROM SEISMIC REFLECTION	Hernández Pérez J. Antonio, González Escobar Mario y Martín Arturo	División de Ciencias de la Tierra, CICESE, México
Wed 24	17:40 – 18:40	S05-2 POSTER TEMPERATURE HISTORY OF THE ORANGE BASIN OBTAINED FROM CRUSTAL MODELS	Hirsch Katja, Scheck-Wenderoth Magdalena, Paton Douglas, van Wees Jan-Diederick y Cloetingh Sierd	GeoForschungsZentrum Potsdam, Germany
Wed 24	17:40 – 18:40	S05-3 POSTER BRITTLE MESOSTRUCTURAL KINEMATICS IN THE LAKE OKANAGAN FAULT ZONE: IMPLICATIONS FOR EOCENE AND YOUNGER DEFORMATION IN THE SOUTHERN CANADIAN CORDILLERA	Osadetz Kirk, Eyal Yehuda y Feinstein Shimon	Geological Survey of Canada, Canada
Wed 24	17:40 – 18:40	S05-4 POSTER CONTINENTAL RIFTING WITH FLAT MOHO	Thybo Hans, Nielsen Christoffer y Lyngsie Stig	University of Copenhagen, Denmark
Wed 24	17:40 – 18:40	S05-5 POSTER SUBSIDENCE INDUCED BY MAGMATIC ACTIVITY	Thybo Hans y Sandrin Alessandro	University of Copenhagen, Denmark
Wed 24	17:40 – 18:40	S05-6 POSTER CRUSTAL STRUCTURE OF THE OSLO GRABEN: PRELIMINARY RESULTS FROM MAGNUS-REX, CRUSTAL SCALE REFRACTION PROFILE	Thybo Hans, Stratford Wanda, Faleide Jan Inge, Olesen Odlev y Tryggvason Ari	University of Copenhagen, Denmark
Wed 24	17:40 – 18:40	S05-7 POSTER SEDIMENTARY BASIN EVOLUTION IN SOUTH ASIA: EXAMPLES FROM WESTERN CHINA	Mooney Walter D.	United States Geological Survey, USA
Session 6: Volcano failure Chairs: Alessandro Tibaldi and Derek Rust				
Thu 25	9:00 – 9:30	S06-1 GROWTH AND FAILURE OF VOLCANOES: A LESSON FROM NISYROS (GREECE) BY FIELD AND OFFSHORE DATA, AND ANALOGUE MODELLING	Tibaldi Alessandro, Papanikolaou Dimitri, Pasquarè Federico y Nomikou Paraskevi	Università degli Studi di Milano Bicocca, Italy
Thu 25	9:30 – 9:50	S06-2 LONG-TERM EVOLUTION OF INDIVIDUAL VOLCANOES AND VOLCANIC SYSTEMS RECORDING LITHOSPHERIC PROCESSES. THE EXAMPLE OF THE CARPATHIAN-PANNONIAN REGION (CENTRAL-EASTERN EUROPE)	Szakacs Alexandru, Seghedi Ioan y Pécskay Zoltán	Sapientia University, Romania
Thu 25	9:50 – 10:10	S06-3 UNSTABLE VOLCANOES AT THE EASTERN MEXICAN VOLCANIC BELT, IMPLICATIONS FOR NON-MAGMATIC TRIGGERS	Carrasco-Núñez Gerardo, Díaz-Castellón Rodolfo, Siebert Lee, Hubbard Bernard, Sheridan Michael y Rodríguez Sergio	Centro de Geociencias, UNAM, México
Thu 25	10:10 – 10:30	S06-4 THE CALDERA DE MALPASO AND THE EL OCOTE IGNIMBRITE, AGUASCALIENTES, MÉXICO	Nieto Obregón Jorge y Aguirre Díaz Gerardo de Jesús	Facultad de Ingeniería, UNAM, México
Coffee break				
Session 7: Volcanism and geodynamics Chairs: Luis Delgado and Ioan Seguedi				
Thu 25	11:00 – 11:20	S07-1 BASEMENT CONTROL ON THE OCCURRENCE OF RAPAKIVI GRANITE AND RELATED LAVAS IN THE WESTERN UNITED STATES: EVIDENCE FROM THE SUBVOLCANIC LITTLE CHIEF STOCK, DEATH VALLEY CALIFORNIA	Tormey Daniel	ENTRIX, Inc., USA
Thu 25	11:20 – 11:40	S07-2 CONTROLS ON EMPLACEMENT OF HYPABYSSAL SHEETS: INSIGHTS FROM THE ERODED THVERFELL VOLCANIC CENTRE IN ICELAND	Rust Derek, Tibaldi Alessandro, Vezzoli Luigina y Pasquarè Federico	University of Portsmouth, United Kingdom
Thu 25	11:40 – 12:00	S07-3 GEOCHEMISTRY AND TECTONIC SETTING OF THE EARLY CRETACEOUS ZACATECAS VOLCANIC COMPLEX, MÉXICO	Escalona Alcázar Felipe de Jesús, Delgado-Argote Luis A., Velasco Tapia Fernando y Nebel Oliver	División de Ciencias de la Tierra, CICESE, México

Thu 25	12:00 – 12:20	S07-4 ENVIRONMENT AND AGE OF EMPLACEMENT OF PLUTONIC COMPLEXES FROM THE SOUTHWESTERN MARGIN OF THE PENINSULAR RANGES BATHOLITH, BAJA CALIFORNIA, MÉXICO	Delgado-Argote Luis A., Peña-Alonso Tomás A., Weber Bodo, Molina-Garza Roberto, Böhnel Harald y Valencia Víctor	División Ciencias de la Tierra, CICESE, México
	12:20 – 12:40	S07-5 COMPARING TWO PLUTONS OF THE NUEVO ROSARITO PLUTONIC COMPLEX, SOUTHERN PENINSULAR RANGES BATHOLITH, BAJA CALIFORNIA, MÉXICO	Peña-Alonso Tomás A., Delgado-Argote Luis A. y Weber Bodo	División de Ciencias de la Tierra, CICESE, México
Lunch				
Session 8: Lithosphere-asthenosphere interactions, baby plumes and paleostress Chairs: Larissa Dobrzhinetskaya and Irina Artemieva				
Thu 25	14:00 – 14:30	S08-1 RECYCLING OF NITROGEN AND BORON INTO EARTH'S INTERIOR THROUGH DEEP SUBDUCTION	Dobrzhinetskaya Larissa, Wirth Richard, Yang Jingsui y Green Harry	University of California at Riverside, USA
Thu 25	14:30 – 14:50	S08-2 IN A SEARCH OF THE LITHOSPHERE-ASTHENOSPHERE BOUNDARY: A REVIEW	Artemieva Irina	Copenhagen University, Denmark
Thu 25	14:50 – 15:10	S08-3 THE ROLE OF FINGER-LIKE BABY PLUMES IN THE GENESIS OF MIOCENE-PLEISTOCENE ALKALIC BASALTIC VOLCANIC FIELDS FROM THE WESTERN PART OF THE CARPATHIAN – PANNONIAN REGION, CENTRAL EUROPE	Seghedi Ioan, Szakacs Alexandru, Kadosa Balogh y Pécskay Zoltán	Institute of Geodynamics, Romania
Thu 25	15:10 – 15:30	S08-4 MICROTECTONIC ANALYSIS OF THE NORTHERN SLOPE OF ANCESTRAL MOUNT BAO, PHILIPPINES	Lagmay Alfredo Mahar Francisco y Caranto Geoffrey	University of the Philippines, Philippines
Thu 25	15:30 – 15:50	S08-5 LATE CENOZOIC AND MODERN STRESS FIELDS IN THE WESTERN FARMS (IRAN)	Lacombe Olivier, Mouthereau Frédéric y Amrouch Khalid	Université Pierre et Marie Curie, Paris, France
Coffee break				
Session 9: Poster session 2				
Thu 25	16:30 – 17:30	S09-1 POSTER COMPOSITIONAL HETEROGENEITY OF THE CONTINENTAL UPPER MANTLE HIDDEN IN SEISMIC MODELS	Artemieva Irina	Copenhagen University, Denmark
Thu 25	16:30 – 17:30	S09-2 POSTER OBSERVATIONS OF SEISMIC ANISOTROPY IN THE GULF OF CALIFORNIA REGION AS EVIDENCE OF LITHOSPHERE-ASTHENOSPHERE INTERACTION	Obrebski Mathias y Castro Raúl	Institut de Physique du Globe de Paris, France
Thu 25	16:30 – 17:30	S09-3 POSTER SEISMIC ANISOTROPY OF THE CRUST AND UPPER MANTLE BENEATH EAST AFRICA FROM JOINT INVERSION OF SKS AND P RECEIVER FUNCTIONS	Obrebski Mathias, Kiselev Sergey, Montagner Jean-Paul y Vinnik Lev	Institut de Physique du Globe de Paris, France
Thu 25	16:30 – 17:30	S09-4 POSTER PERMIAN RHYOLITIC VOLCANISM IN THE SIRINIA BASIN (SE ROMANIA-EASTERN EUROPE) - VOLCANOLOGICAL FEATURES	Seghedi Ioan	Institute of Geodynamics, Romania
Thu 25	16:30 – 17:30	S09-5 POSTER ATTENUATION AND SEISMIC TOMOGRAPHY STUDIES IN THE TRES VIRGENES VOLCANIC AND GEOTHERMAL REGION, BAJA CALIFORNIA SUR, MÉXICO	Wong Victor	División de Ciencias de la Tierra, CICESE, México
Session 10: Basin processes and case studies Chairs: Magdalena Scheck-Wenderoth and Hans Thybo				
Fri 26	9:00 – 9:30	S10-1 THERMO-MECHANICAL MODELS FOR BASIN (DE)FORMATION	Cloetingh Sierd, van Wees Jan-Diederik y Beekman Fred	VU University, Netherlands
Fri 26	9:30 – 9:50	S10-2 INTRACRATONIC BASINS: ROLE OF MANTLE DYNAMICS AND METASOMATISM	Artemieva Irina	Copenhagen University, Denmark
Fri 26	9:50 – 10:10	S10-3 COMPARING DIFFERENT STYLES OF SEDIMENTARY BASINS IN THE BARENTS SEA	Faleide Jan Inge, Planke Sverre y Team PETROBAR	University of Oslo, Norway
Fri 26	10:10 – 10:30	S10-4 FLEXURE OF THE EURASIAN PLATE, LITHOSPHERIC BULGE AND DEVELOPMENT OF THE WESTERN FORELAND BASIN OF TAIWAN	Lacombe Olivier, Mouthereau Frederic y Tensi Julián	Université Pierre et Marie Curie, Paris, France
Fri 26	10:30 – 10:50	S10-5 THE SINU ACCRETIONARY PRISM (COLUMBIA) SHORTENING/GRAVITY TECTONICS INTERACTION PROCESSES FROM ANALOGUE MODELLING	Ellouz-Zimmermann Nadine, Deville Eric y Benguigui Amran	Institut Français du Pétrole, France
Fri 26	10:50 – 11:10	S10-6 "SOFT" OROGENIC COLLISION: WHAT DOES IT MEAN - THE CARPATHIANS EXAMPLE	Matenco Liviu, Krezsek Csaba, Merten Sandra, Schmid Stefan, Cloetingh Sierd y Andriessen Paul	VU University, Netherlands

Fri 26	Coffee break	
Fri 26	11:40 – 12:40	Panel discussion
	Lunch	

ILP Introduction

Founding partner of International Year of Planet Earth: Frontiers in integrated solid Earth sciences

Cloetingh S.A.P.L. y Negendank J.F.W.
Vrije Universiteit
sierd.cloetingh@falw.vu.nl

The International Lithosphere Program (ILP) aims to elucidate the nature, dynamics, origin and evolution of the lithosphere through international, multidisciplinary geoscience research projects and coordinating committees. ILP promotes multidisciplinary research projects of interest to both the geological (IUGS) and geophysical (IUGG) communities. ILP seeks to achieve a fine balance between: addressing societal needs, e.g. understanding natural catastrophes and other solid Earth processes that affect the biosphere, providing information for improved resource exploration and environmental protection and satisfying scientific curiosity.

The Integrated Solid Earth perspective is key to the mission of ILP since:

- The Lithosphere is the connection between the deep Earth and the Earth's surface;
- The Lithosphere is the topic for focused cooperation between geology, geophysics and geotechnology;
- Breakthroughs in the study of the Lithosphere can only be achieved through integration of imaging and monitoring, reconstruction and process modelling.

The deep Earth may sound remote from everyday concerns, but it has strong relevance for humanity. The structure and processes of the deep Earth may sound remote from everyday concerns, but both have strong relevance for humanity's basic needs, such as supply of water and resources, protection against natural hazards, and control of the environmental degradation of the Earth.

We focus on two key questions: i) how can we better understand mass transfer (see below) at Earth's surface, and its feedback with deep Earth recycling?; ii) how can our improved understanding of Earth processes lead to better prediction?

Specific projects invoke: a) Drilling: continental and ocean crust; b) in situ and 'real time' monitoring programmes including satellite, surface and borehole monitoring instruments; c) geomechanical and geochemical laboratory facilities; d) geo-information databases containing historical data on global and regional changes in combination with the vulnerability of natural and human habitats; e) building a knowledge base on the modelling and simulation of Earth motions and topography through space and time, as well as on risk and impact assessment.

Coupled Deep Earth and Surface Processes. The modern Earth system approach requires a comprehensive integration of existing databases, with the capacity to expand to allow for storage and exchange of new data collected during the growth of the programme. Unification and coupling of existing modelling techniques is needed to achieve full integration of what are currently discipline-oriented approaches and to expand fully 'next generation' 3D applications. Furthermore, flexible exchange for 'feed-back loops' in the quantification of Earth processes is needed at the interface between databases and modelling tools. Consequently, major investments in Information Technology are called for so as to expand existing computer hardware and software facilities.

Session 1

Basin processes

Chairs:

Noëlle Schoelkopf

Patrick Unternehr

S01-1

NEW ASPECTS OF MAGMATISM IN RIFTING AND BASIN FORMATION

Thybo Hans

*Department of geography and geology,
University of Copenhagen, Denmark*

thybo@geo.ku.dk

It is debated if heating and magmatic processes cause rifting or if rifting processes cause magmatic activity. However, rifting is always accompanied by magmatic intrusion into the crust and volcanism at the surface, although usually considered a secondary process. The stretching factor in rift zones can be estimated as the relation between the initial and the final crustal thickness provided that the magmatic addition to the crust is insignificant. Recent research has demonstrated substantial magmatic intrusion into the crust in the form of sill like structures in the lowest crust in the presently active Kenya and Baikal rift zones and the DonBas palaeo-rift zone in Ukraine. This result is surprising as the Kenya Rift is usually considered "wet" due to large amounts of volcanic products associated with the rifting processes whereas the Baikal Rift is considered "dry" due to very little volcanism. This finding has strong implications for estimation of stretching factor, which in the case of Baikal Rift Zone is around 1.7 but direct estimation gives a value of 1.3-1.4 if the magmatic addition is not taken into account. Similar differences may be expected for other rift zones, including palaeo-rifts, and may indicate that much more stretching has taken place on rift systems than hitherto believed.

Wide sedimentary basins may form around aborted rifts due to loading of the lithosphere by sedimentary and volcanic in-fill of the rift. This type of subsidence will create wide basins without faulting. The Norwegian-Danish basin in the North Sea area also has subsided gradually during the Triassic without faulting, but only few rift structures have been identified below the Triassic sequences. We have instead identified several structures in the crust which may be interpreted as mafic intrusions in the form of large batholiths, typically more than 100 km long, 20-40 km wide and 20 km thick. The heating by a series of such large intrusions would have lifted the surface of the Earth by about 2 km. Before cooling much of the uplift would be eroded. The subsequent subsidence due to solidification and cooling of the magma would create a basin type, which is similar to loading basins.

I will discuss these new aspects of rifting and basin formation with focus on the magmatic processes, the structure of the magmatic intrusions, as well as the subsidence history in the studied locations.

S01-2

STRUCTURAL AND THERMAL MODELLING OF THE FORELAND BASIN OF CHIAPAS-TABASCO, MÉXICO

Ortuño Arzate Felipe¹ y Sassi William²¹*Instituto Mexicano del Petróleo*²*Institut Français du Pétrole*

fortuno@imp.mx

An integrated modelling of the foreland basins in the Chiapas-Tabasco region, SE Mexico was carried out with

multidisciplinary approach combining geological modelling and structural analysis. The timing of the structural evolution of the Comalcalco and Pilar-Reforma-Akal area and the elements and processes of the mesozoic petroleum system were investigated using 2 SW-NE basin scale cross sections. These seismic cross sections were interpreted using section balancing techniques and forward structural reconstructions in order to constrain the amount of tectonic shortening, the geometry of the pre-deformation structural units and the trajectories of the major faults.

In addition, all well log data of the Tabasco basins were used to reconstruct thermal history in order to delineate new potential investigations of the source-reservoir rocks distributions in the light of both new data acquisition and new modelling capabilities of basin and structural modelling software gathered since ten years ago.

S01-3

3D STRUCTURE OF THE ORANGE BASIN, SOUTHWEST AFRICAN CONTINENTAL MARGIN

Hirsch K.K.¹, Scheck-Wenderoth M.¹, Bauer K.¹,
van Wees J. D.², Cloetingh S.A.P.L.² y Beekman F.²

¹*GeoForschungsZentrum Potsdam*²*Vrije Universiteit Amsterdam, Netherlands*

hirsch@gfz-potsdam.de

The passive margin of the South Atlantic shows typical features of a rifted volcanic continental margin, encompassing seaward dipping reflectors, continental flood basalts and high-velocity/density lower crust at the continent-ocean transition, probably emplaced during initial seafloor spreading in the Early Cretaceous.

The Springbok profile offshore western South Africa is a combined transect of reflection and refraction seismic data. Here we present the results of an analysis of the seismic velocity structure in combination with gravity modelling and isostatic modelling to unravel the crustal structure of the passive continental margin from different perspectives.

The velocity modelling revealed a segmentation of the margin into three distinct parts of continental, transitional and oceanic crust. As observed at many volcanic margins, the lower crust is characterised by a zone of high velocities with up to 7.4 km/s. The conjunction with gravity modelling affirms the existence of this body and at the same time substantiated its high densities. Both approaches identified the body to have a thickness of about 10 km.

Isostatic modelling was applied to predict average crustal densities if the margin was isostatically balanced. The results imply isostatic equilibrium over large parts of the profile, smaller deviations are supposed to be compensated regionally. The calculated load distribution along the profile implies that all pressures are hydrostatic beneath a depth of 45 km.

The findings on the crustal structure of the margin along the Springbok profile have been transformed to an area farther south in the Orange Basin where deep seismic data are missing to image the deeper crust. A combined approach of isostatic and gravimetric modelling was chosen to unravel the crustal structure.

Based on interpreted seismic reflection data, a 3D geological model of the uppermost crust was constructed. Subsequently, an isostatic calculation (Airy's model) using a homogeneous middle and lower crust was applied to this geological model to determine the position of the Moho for an isostatically balanced system.

Isostatic sensitivity tests were applied to the model, and their gravity response was validated against different crustal structures for the basin. The best-fit model requires dense, presumably mafic material, in the middle and lower crust beneath the basin and an abrupt change to less dense material near the coast to reproduce the observed gravity field.

Session 2

Gulf of California and NW Mexico

Chairs:

Walter Mooney

Arturo Martín-Barajas

S02-1

**NEOGENE EVOLUTION OF RIFTING IN
THE NORTHERN GULF OF CALIFORNIA:
TECTONOSTRATIGRAPHIC ANALYSIS OF
SEISMIC REFLECTION AND BOREHOLE DATA**

Martín Arturo¹, Helenes Javier¹, González Escobar Mario¹, García Juan¹, Aragón Manuel¹, Carreño Ana Luisa² y Pacheco Martín³

¹*División de Ciencias de la Tierra, CICESE*

²*Instituto de Geología, UNAM*

³*PEMEX Coordinación de Plays Zona Norte*

amartin@cicese.mx

The northern Gulf of California contains >5,000 of sedimentary fill, which constitutes an important record of Neogene rifting and tectonic subsidence. The interpretation of several exploration wells, and ~4500 km of seismic reflection data from PEMEX (Mexican national oil company) indicate that the northern Gulf contains two parallel, north-south trending basin systems separated by a basement-high. The eastern basin system is tectonically inactive and includes three main sedimentary sequences, which were identified in boreholes and seismic sections. The lower sequence (A) directly overlies the acoustic basement and has parallel reflectors and a largely uniform thickness that reaches up to 1.5 km in the largest basin and gradually pinches out toward the lateral margins. Based on borehole samples, sequence A is marine, and yields late Miocene microfossils (<12 Ma). However, sequence A is much younger (latest Miocene to Pliocene) beneath the modern delta of the Colorado River, and likely reflects a time-transgressive marine incursion.

Sequence B conformably overlies sequence A, and is characterized by up to 2 km growth strata with a fanning geometry that show a clear genetic relationship to the major transtensional faults that control the segmentation of the two basin systems. In the northern end of the Gulf sequence B is composed of Pliocene sandstone-siltstone-mudstone deltaic deposits from the Colorado River that locally reach 3 km in thickness. Sequence C in the eastern basin system is comparatively thin (<800 m) and includes several unconformities, but is much less affected by faulting. In contrast, sequence C in the active basins along the western system (Wagner, Consag and Upper Delfin basins) is a much thicker (up to 2 km) growth sequence. Marked variations in sequence C in the different basin systems clearly demonstrate a major westward shift of deformation and subsidence at this time. In summary, sequence A was deposited across most of the northern gulf in the late Miocene, sequence B marks the onset of two discrete transtensional basin systems controlled by both low and high-angle faults in late Miocene-Pliocene, and sequence C marks the regional migration of plate-margin shearing to its present location in the western gulf. Thermal affects associated with abundant intermediate to felsic volcanism along the western rift basins of the northern gulf likely controlled the asymmetric partitioning plate margin shearing during the most recent phase of oblique rifting.

S02-2

**AN ARC-COLLISION ZONE IN NORTHERN
BAJA CALIFORNIA, MÉXICO, DETECTED
FROM MAGNETOTELLURIC DATA**

Pamplona Uriel y Romo Jones José Manuel

División de Ciencias de la Tierra, CICESE

upapl@icicese.mx

Enhancement of electrical conductivity in the rocks of the upper crust highly depends on the presence of fluids and/or conductive minerals. Hence, the assessment of subsurface conductive anomalies may contribute to understand the tectonic evolution of Baja California peninsula. In this work we show an electrical resistivity model of the crust, obtained from a magnetotelluric transect through Sierra San Pedro Mártir (SPM), in northern Baja California, México. The profile consists of 26 magnetotelluric (MT) sites and has a length of ~110 km, across some major tectonic structures occurring in Baja California's crust. We used a set of magnetotelluric invariant impedances and a regularized inversion technique to estimate a 2-D resistivity model of the crust. The resulting resistivity model reveals a high conductivity anomaly in the west side of the Sierra San Pedro Mártir, dipping towards the east. This anomaly is interpreted as a recently postulated collision zone between Alisitos island arc and North American plate, developed during an important accretion episode in Cretaceous time. On the other hand, it is observed an increase in the conductivity at a depth of about 20 km, which could be associated to fluids trapped in the brittle-ductile transition zone. This may suggest the presence of a weakness zone, in agreement with some existent rheological models.

S02-3

**SEISMIC REFLECTION IMAGES OF
THE WESTERN FARALLON BASIN,
SOUTHERN GULF OF CALIFORNIA, MÉXICO**

Piñero Lajas Doris¹, González Fernández Antonio¹, López Martínez Margarita¹, Lonsdale Peter² y Kluesner Jared²

¹*División de Ciencias de la Tierra, CICESE*

²*Scripps Institution of Oceanography*

dpinero@cicese.mx

Our study is based on 800 km of high resolution 2D multichannel seismic (MCS) data collected in 2006 by CICESE (Centro de Investigación Científica y de Educación Superior de Ensenada) and Scripps Institution of Oceanography in the southern Gulf of California. The MCS seismic sections were used to investigate the structure and stratigraphy of the western Farallon basin and other smaller basins in the Baja California eastern margin. Most of the previous tectonic interpretations in this area were based on bathymetric data.

We show a very detailed image of the sub-bottom structure up to 2-4 s two-way travel time (aprox. 2 km). We constrain the depth to the acoustic basement and we try to establish the different types of basement: a first type, appears as a continuous, high amplitude feature in the western part of the study area, that we identify as continental, and can be correlated with some granite outcrops located in the southern Gulf of California islands, and with some dredge samples in the area; we also identify possible volcanics in certain areas; in the eastern part, near the Farallon

spreading center, the acoustic basement is more discontinuous, and the seismic sections show a number of diffracted waves that can be related to sills.

We also present detailed images of active and inactive faulting that affects the basement as well as the sediments. Some of these faults can be correlated between lines. Another important feature is the identification of a BSR (bottom simulating reflector) in some of the seismic lines.

Session 3

Gulf of Mexico and its surroundings

Chairs:

Fernando Sánchez-Ferrer

Gary Gray

S03-1

TECTÓNICA GRAVITACIONAL Y MOVIMIENTOS CORTICALES CENOZOICOS EN LA MARGEN OCCIDENTAL DEL GOLFO DE MÉXICO

Martínez Reyes Juventino¹, Rangin Claude², Le Pichon
Xavier², Andréani Louis², Le Roy Charlotte², Aranda
García Mario³, Flotté Nicolas² y Husson Laurent²

¹Centro de Geociencias, UNAM

²Collège de France, Aix-en Provence

³PEMEX Exploración y Producción

jmr@geociencias.unam.mx

Se presentan los trabajos realizados por el grupo de Geodinámica del Colegio de Francia en colaboración con el Centro de Geociencias de la UNAM, en el marco del proyecto Golfo de México apoyado por las compañías petroleras TOTAL y PEMEX. Estos trabajos ilustran las relaciones estructurales y cinemáticas existentes en el Neógeno entre la tectónica gravitacional y de transcurrencias laterales con los movimientos corticales cenozoicos profundos.

Los deslizamientos superficiales observados en la plataforma texana se propagan hacia el Sur sobre la plataforma mexicana a lo largo de la Falla Oriental Mexicana (East Mexican fault). Esta tectónica gravitacional principalmente extensiva en Texas y de transcurrencia lateral derecha en México, es inducida por una tectónica cortical profunda observable debajo de la zona de despegue principal. En territorio mexicano esta tectónica es claramente neógena, transtensiva en el norte y transpresiva en el sur. Se le reconoce en tierra sobre la planicie costera donde se caracteriza por cizallamientos N030°W y cuencas en "pull-apart" asociadas, alimentadas por volcanismo alcalino poco diferenciado. Esta zona de cizallamientos afecta la planicie costera sobre una banda de más de 100 kilómetros que se extiende desde el frente de la Sierra Madre Oriental al Oeste hasta la margen profunda del Golfo al Este. Aquí alcanza la zona de transición entre la corteza continental y la corteza oceánica que corresponde al emplazamiento de la falla Oriental Mexicana, falla que ha sido considerada mesozoica y ligada a la apertura del Golfo de México. Si esto es así, es necesario admitir entonces su reactivación neógena, si no, se trata entonces de una falla neoformada, propuesta que apoyamos en este trabajo.

El sistema de cizallamiento lateral derecho sub-meridiano a lo largo de la Falla Oriental Mexicana parece conjugarse con el sistema de cizallamiento lateral izquierdo NW-SE de la Falla de Veracruz (Veracruz fault), de posición más continental. Esta última guía el movimiento neógeno entre las placas Norteamericana y Caribe, movimiento ampliamente documentado al sur a lo largo del sistema Polochic-Motagua. En la región central de México la Falla de Veracruz limita el continente "estable" de una microplaca, el Bloque Meridional Mexicano (South Mexican block), actualmente en curso de desprendimiento y transferencia a la placa Caribe, como ha sido el caso en el pasado del bloque Chortís. La actividad conjunta de esas dos fallas constituye un sistema conjugado que da testimonio de un estiramiento NW-SE de la margen mexicana del Golfo. Esta tectónica de estiramiento ligada a la huida hacia el SE de la placa Caribe, es acompañada desde el Mioceno inferior por el colapzamiento del arco volcánico paleógeno de la Sierra Madre Occidental debido al súbito retiro de la subducción de la placa Farallón, y por la tectónica Basin and Range del continente norteamericano.

Los estudios realizados (que ahora se continúan hacia la región de Tabasco/Chiapas) han permitido interpretar la deformación de

la margen mexicana del Golfo de México durante el Neógeno términos de deslizamiento de la corteza adelgazada sobre el Moho.

S03-2

COB DEEP STRUCTURE IN A SHEAR MARGIN (WESTERN MAIN TRANSFORM - OFFSHORE VERACRUZ, SOUTHERN GULF OF MÉXICO)

Román Ramos Juan Rogelio¹, Sánchez Ferrer Fernando²,
Biegert Ed², Cruz Mercado Miguel Angel¹, Bartsch Erik²,
Salomon Mora Luis Enrique¹ y Rosas Lara Carlos¹

¹PEMEX Exploración y Producción

²SHELL

jrromanr@pep.pemex.com

Gravity, magnetic, and heat flow data suggest that the Western Main Transform Shear Margin – (Marton and Buffler [1994] and Ross and Scotese [1988]) is associated with a transform deformation zone having considerable lateral extent. Inboard of this zone lays continental crust, while outboard to the east of the large gravity anomaly associated with this structure lays oceanic crust. The basement complex in the deformation zone is likely to be heavily modified continental crust intruded with magnetic and higher density crustal material.

The Mexican Ridges, in the southwestern Gulf of Mexico, are part of a linear trend of offshore contractional features forming pronounced bathymetric highs parallel to the Mexican coastline. The Mexican Ridges are interpreted as the down-dip contractional part of a linked extensional-contractional belt soling onto a Lower Tertiary detachment horizon. The deepwater foldbelt extends 200 km from onshore Mexico to the abyssal plain (Garrison and Martin, 1973 and Worrall and Snelson, 1989). We ascribed the formation of the Mexican ridges to large-scale gravity sliding, triggered by coastal uplift of the Sierras further west. (5-7 km of uplift according to Gray et al. (2001). Our own palinspastic restoration indicates that folding started in the Middle Miocene, peaked in the Lower Pliocene, and continued to present day. We estimate the total extension/ contraction in the Mexican ridges to be around 11%.

In contrast to the salt-cored Perdido folds further north, or the Campeche folds further south (Fig.1), no evidence of the Late-Jurassic Louann salt is found in the area of the Mexican ridges. The lack of Luanne salt in the Mexican ridges is a result of its tectonic evolution, namely its situation above oceanic crust generated during the opening of the Gulf of Mexico.

It's generally accepted that the regional framework history of the GOM involves a simple two-stage model for the opening of the basin.

The initial stage of crustal stretching was the result of the Gondwana plate (specifically South America) pulling away from North America in a relative NW-to-SE sense. The Yucatan block is interpreted to have initiated a counterclockwise rotation during this phase. The shear margin, or Western Main Transform discussed by Marton and Buffler (1994), Ross and Scotese (1988), and others is usually considered to be the main western transform boundary associated with this Jurassic rifting and the rotation of the Yucatan block.

Towards the end of this initial rifting phase, a great thickness of Louann salt was deposited across the entire basin.

The second stage saw the onset of the emplacement of oceanic crust in the upper Jurassic, which lasted into the Lower

Cretaceous. The spreading center was segmented by many NE-trending oceanic transform faults, which formed during the continued rotation of Yucatan away from the Texas margin. The Yucatan block continued its counterclock-wise rotation with a pole near the straights of Florida.

S03-3

RECONSTRUCTION OF THE DEFORMATION AND FLUID FLOW HISTORY IN THE CÓRDOBA PLATFORM AND VERACRUZ BASIN (MÉXICO): VALIDATION AND CALIBRATION OF A BASIN MODEL

Ferket Helga¹, Swennen Rudy², Ortuño Arzate Salvador³, Guilhaumou Nicole⁴ y Roure François⁵

¹*Vlaamse Instelling voor Technologisch Onderzoek*

²*Katholieke Universiteit Leuven*

³*Instituto Mexicano del Petróleo*

⁴*Museum National d'Histoire Naturelle*

⁵*Institut Français du Pétrole*

helga.ferket@vito.be

An extensive diagenetic study of the main reservoir formations of the Córdoba-Veracruz petroleum system, situated in the Laramide fold-and-thrust belt, revealed the deformation, fluid flow, hydrocarbon system, pressure and temperature through time for that area. Some results contribute directly to petroleum exploration; e.g. the study of the controls on poro-perm distribution in a reservoir analogue; the recognition of two phases of paleokarst and biodegradation; and the demonstrated TSR in deep sulphate-rich reservoirs. Other results provide a more indirect benefit in improving the basin model. Calibration of basin modelling is a common challenge, because often several solutions may be proposed for the same dataset. A detailed study of fluid inclusions in combination with SFTIR analyses and PVT modelling allowed estimating absolute temperature and pressure conditions around the timing of hydrocarbon trapping. These independent data led to a revision of the former accepted models where syntectonic flysch deposition in a flexural basin was neglected. The new model actually integrates much better the different aspects of the fold-and-thrust belt and of an early petroleum system that developed only locally.

In summary, the Cenomanian to Santonian platform developed in a foreland setting with stable carbonate production. With the onset of hinterland deformation, a forebulge with a local karst system formed in relation to a flexural basin receiving flysch sediments. As a result the sedimentary sequence in the west was much thicker than in the east, engendering different timing of maturation. Within an increasingly compression-related stress field, first hydrofractures formed that were filled with host-rock-like cements and later hydrofractures and breccia that were filled with non-equilibrium products. Changing mineralogy, CL, isotopic signature, temperature and salinity indicate a larger fluid circulation. Hydrocarbon migration also took place in the western part of the platform during this phase. Deep reservoirs with anhydritic limestone were subsequently affected by TSR leading to pyrobitumen. Shallower intervals were affected by biodegradation after erosion of the overlying strata. When deformation reached the eastern part of the platform a second phase of paleokarst with seepage and biodegradation affected the frontal reservoirs filled with early accumulated oil. Subsequent burial of the tectonic front by the Veracruz Basin led to a new phase of hydrocarbon migration and formation of the present-day fields.

S03-4

MODELADO DE FLUIDOS Y MIGRACIÓN DE HIDROCARBUROS EN UNA SECCIÓN DE LA REGIÓN PETROLERA DE VERACRUZ

González Mercado Esmeralda¹ y Roure Francois²

¹*Petróleos Mexicanos*

²*Instituto Francés del Petróleo*

gegonzalezlm@pep.pemex.com

Los trabajos de evolución cinemática, diagénesis y de inclusiones fluidas realizados a la fecha, establecen una historia de reconstrucción del flujo de fluidos y de migración de hidrocarburos en la Cuenca de Veracruz. Tomando en consideración, los resultados de estos estudios y los escenarios geológicos que plantea, se presenta el modelado de una sección geológica con el programa Ceres2D.

El modelado de la sección, muestra tres escenarios:

1) Prelaramídico con desarrollo de grandes plataformas de rocas carbonatas donde se llevó a cabo una circulación local de paleofluidos y un posterior desarrollo de karst y estilolitas BPS (Bed Parallel Stylolites).

2) Escenario Laramídico, cuyo cinturón de pliegues cabalgantes produce una sobrecarga litostática, que da lugar a los primeros pulsos de migración de hidrocarburos en el límite oriental de la Plataforma de Córdoba con dirección al Este. Evidencia de este evento es el desarrollo de estilolitas de acortamiento que funcionan como rutas de migración. A fines del Eoceno Medio se emplaza el Frente Tectónico Sepultado y hacia el oriente se desarrolla una cuenca de foreland. La formación del sistema montañoso generó un continuo depósito de sedimentos hacia el oriente, en una cuenca en constante subsidencia.

Para el Eoceno Tardío (33 Ma), comenzaron las primeras manifestaciones de migración en la Cuenca de Veracruz. Las trayectorias de migración se hicieron en sentido vertical, cambiando posteriormente al oeste a causa de la subsidencia y de la carga litostática.

3) El tercer escenario está asociado a la deformación durante el Mioceno Medio y Tardío (Chiapaneca), que reconfiguró la Cuenca de Veracruz al formar altos y depresiones intracuenca. En esta etapa donde se acentúan las trayectorias de migración hacia el frente tectónico, este evento es también identificado por la presencia de inclusiones fluidas de hidrocarburos líquidos y gaseosos.

El Mioceno Superior y Plioceno, representan las etapas de colmatación de la cuenta y las trayectorias de migración se continúan hacia el frente tectónico en la porción occidental de la cuenca y en sentido vertical en el resto de ella.

Las trayectorias de migración obtenidas por el modelo muestran que en la cuenca la migración de hidrocarburos actualmente alcanza niveles estratigráficos del Eoceno.

S03-5

PREDICCIÓN DE LITOFACIES EN AGUAS PROFUNDAS EN UN MARCO TECTÓNICO SEDIMENTARIO

Alzaga Ruiz Humberto¹, Granjeon Didier² y Roure Francois²

¹*Instituto Mexicano del Petróleo*

²*Institute France du Pétrole*

halzaga@imp.mx

El estudio se ubica en la Cuenca del Golfo de México (CGM), en la porción sur que corresponde a la Cuenca Tampico Misantla en el estado de Veracruz.

El trabajo se realizó básicamente con información sísmica 2D en tiempo (twf), e información de pozos disponibles. El estudio consiste de tres etapas, una primera de interpretación y correlación sismoestratigráfica entre la planicie costera y la CGM, posteriormente la conversión de tiempo a profundidad y una tercera etapa que comprende el modelado cinemática y estratigráfico sedimentario digital.

Desde el punto de vista tectónico-sedimentario la geodinámica de la Cuenca del Golfo de México comprende cuatro periodos de evolución sedimentaria; los depósitos de rift, depósitos postrift, depósitos syn-orogénicos y post-orogénicos. Nos enfocamos a los depósitos sedimentarios syn-orogénico y post-orogénico (Terciario).

De esta manera los procesos sedimentarios que contribuyen a los depósitos del Paleógeno son la formación de la cadena orogénica Sierra Madre Oriental (SMO), originando una cuenca por carga tectónica de subsidencia flexura, y la elevación de la cadena montañosa (SMO), provocando un cambio en la sedimentación de calcárea a siliciclastica, dando lugar a grandes depósitos de deslizamientos, "slumps" y turbiditas.

En los depósitos post-orogénico la subsidencia de flexura cesan, la tasa de sedimentación es mayor, este cambio en los procesos tectónicos impactara en la sedimentación siliciclastica originando playas y barras de arena azolvando la cuenca, provocando una sedimentación progradante (clinoformas progradantes) con dirección al oriente del CGM.

El aporte y carga sedimentaria que sobrepasa la velocidad de subsidencia de la margen pasiva del CGM para el Neógeno, darán lugar a un sistema de fallas listricas y esta a su vez una re-depósito de litofacies en aguas profundas ocasionando deslizamientos y "slumps".

En la predicción de litofacies el porcentaje de arena es importante en el volumen total de sedimentos, la descarga de agua fluvial para el transportar también y generar una progradacion de sedimentos sobre el borde de la plataforma, estos pierden el equilibrio y se redepositan como flujos de detritos y "slumps" en aguas mas profundas.

Session 4

HC resources

Chairs:

Francois Roure

Felipe Ortuño

S04-1

PROGRESS IN EXPLORATION: MAIN EXPLORATION BREAKTHROUGH AND EXPLORATION RESULTS FROM SOME FOLD BELTS PETROLEUM REGIONS

Mathieu Yves

Institut Français du Pétrole

yves.mathieu@ifp.fr

Global Petroleum Industry Breakthroughs are listing with their consequences in hydrocarbon exploration success. three main stages can be defined:

- a 1st stage before subsurface imaging by seismic 1D corresponding to a hazardous exploration based only on outcrops datas,

- a 2nd stage follows to the 80's corresponding to a constant amelioration of the tools used in exploration and local calibration and knowledge,

- a 3rd stage from the 80's to present day by basin modelling and simulations increasing prediction of traps and fluids translating a rationalisation of the exploration.

Three cases of Fold Belts petroleum regions are then studied: The Chaco in Bolivia, the Zagros from Tukey to Iran and the Potwar in Pakistan. On these three fold belts the results given by exploration wells (wildcats) and their success (discoveries) are reporting year per year and by the main stage of exploration. They show that the success of the exploration is clearly dependant of the techniques used and local knowledges.

Nevertheless the success ratio of wildcats are always limited and great efforts are still requiring to increase these one's and to rich the success ratios of others types of petroleum contexts.

S04-2

THE EFFECTS OF TECTONIC HISTORY AND FRAMEWORK ON PETROLEUM SYSTEMS AND RESOURCES IN EAGLE PLAIN BASIN AND ENVIRONS, YUKON TERRITORY, CANADA

Osadetz Kirk¹, Lane Larry¹, Chen Zhuoheng¹ y Bird Timothy²¹*Geological Survey of Canada Calgary*²*Canadian Natural Resources Ltd.*

kosadetz@nrcan.gc.ca

Eagle Plain Basin (EPB) (65°N-67.5°N; 136°W-140°W) in Yukon Foldbelt covers ~20,600 km². The central 13,600 km² rectangular region is underlain by Cretaceous bedrock. Surrounding this is an area underlain by Paleozoic bedrock west of the Richardson Mountains (RM). Proterozoic successions underlie the entire region and crop out nearby. The lower Paleozoic succession comprises Cambrian-Middle Devonian strata deposited during rifting and thermal subsidence coeval with Paleopacific margin formation. EPB is roughly coincident with Porcupine Platform (PP), part of a rifted cratonic fragment, Yukon Stable Block (YSB), that was persistently separated from Mackenzie Platform (MP) of cratonic North America by a deep, fault-bounded depression, Richardson Trough (RT). Sloss-like sequences on MP are not evident on PP. The duration and setting of early Paleozoic subsidence are longer than, and far-field from a passive margin suggesting additional lithospheric loads.

Middle Devonian, carbonate platforms on both YSB and the craton were "drowned" by a transgression affecting much of the Paleopacific continental margin. Downlapping distal Ellesmerian foreland basin clastics followed in Late Devonian time. The Upper Devonian-Lower Carboniferous clastic wedge migrates southward and coarsens and shallows upward, indicating progressive encroachment of the Ellesmerian deformation, which deformed northern PP and RT. During the Late Permian-Late Jurassic lacuna, erosion of Paleozoic successions outlined Eagle Arch, which separates a southerly dipping homoclinal Paleozoic succession on its south limb from a deformed Paleozoic succession on its north limb. Subsidence and sedimentation resumed in the Neocomian, with deposition of a clastic succession that indicates northward Cordilleran foreland basin progradation, in the upper part, over cratonically derived strata, in the lower part. The region was deformed during Maastrichtian-Miocene Laramide orogenesis. The deformation is characterized by involvement of the Proterozoic succession, tectonic inversion of early Paleozoic extensional features, and multiple detachments and interfering fold patterns in the Phanerozoic succession indicating north-south and east-west directed shortening, with complicated, overlapping relationships. Inheritance and inversion are obvious, but kinematic and dynamic models are needed. Especially obscure are effects and impacts accompanying Amerasian Arctic Ocean basin opening, which some attribute to Jurassic-Early Cretaceous rift and anticlockwise rotation of northern Alaska, a hypothesis with severe tectonic consequences for YSB and its environs, although there are no such direct or easily interpreted manifestations. The complex Tertiary structures reflects multiple tectonic drivers and complex boundary conditions that evolved progressively. Whereas Mackenzie and Ogilvie mountains define an imposing 1200 km regional arc, the smaller Yukon and Beaufort foldbelts define a smaller arcuate belt perched on the northern limb of the larger one, so that northward shortening in the Ogilvie Mountains interferes with coeval eastward shortening in EPB and RM. Tectonic history controls petroleum potential and risks. 2.37X10⁹m³ natural gas, and 1.75X10⁶m³ crude oil have been found, with many shows, throughout section and across the basin. The resource endowment is 67.39-339.94X10⁹m³ natural gas and 20.95-146.98X10⁶m³ crude oil. Plays in the upper Paleozoic succession overlie thermally mature sources, below regional seals. Intriguing high risk stratigraphic plays exist in Paleozoic carbonates, while conceptual plays in the Devonian-Carboniferous flysch have shows, but were not quantified.

S04-3

A NEW THERMAL MATURATION MAP OF THE SILURIAN-DEVONIAN GASPÉ BELT BASIN IN THE QUÉBEC APPALACHIANS

Roy S., Bertrand R. y Malo M.

INRS

mmalo@ete.inrs.ca

The Silurian-Devonian Gaspé Belt is the largest middle Paleozoic belt in the Canadian Appalachians. The most complete stratigraphic record of Upper Ordovician to Middle Devonian rocks of this belt is found in the Gaspé Peninsula. Sedimentary basins of middle Paleozoic belts in the northern Appalachians, deformed during the Middle Devonian Acadian orogeny, are viewed as successor basins formed after early Paleozoic orogenic events, such as the Taconian orogeny.

The thermal maturation map is based on reflectance of organic matter R_o measured on randomly oriented organic particles under non-polarized, reflected light. The R_o of zooclasts and solid bitumen was converted into R_o vitrinite-equivalent. The R_o values in the Silurian-Devonian rocks of the Gaspé Belt basin vary from 0.4 to 8.0, or from the immature stage of hydrocarbon generation to the sterile epizone. Cambrian-Ordovician rocks underlying the Gaspé Belt basin, below the Taconian unconformity, are significantly higher than those of adjacent Silurian-Devonian rocks.

Surface maturity contours in the Silurian-Devonian Gaspé Belt basin generally follow geological contacts and regional folding. Higher R_o values are measured in the core of anticlines, whereas lower R_o values (oil window) occur in synclines of younger Devonian rocks. This suggests that thermal maturity is mainly due to burial. At the same stratigraphic level, the thermal maturity varies greatly from an area to the other due to the local changes in the basin due to tectonics and/or sedimentary patterns. In general, the thermal maturation slightly increases from the east to the west, but significantly increases from both northern and southern parts of the basin toward the centre. Moreover, a north-south arch of high maturation values divides the basin in an eastern and a western part.

The surface maturity contours of high values crosscut folded geological contacts in the northern part of the basin. Local high maturity of sedimentary rocks is due to Devonian intrusions and suggests that folding occurred before the emplacement of intrusion at 370 Ma. In western part of the basin, lower Devonian rock assemblages of the Gaspé Sandstones are more mature south of the Causapsal fault. This could be explained by an accelerated subsidence of the basin south of the fault during the early Devonian. High values of R_o of the lower Devonian Fortin Group turbidites in the western part of the basin can also be explained by a significant burial due this subsidence and deposition of younger sedimentary rocks which are now eroded. In southern part of the basin, Silurian rocks are less mature around the Cambrian-Ordovician Maquereau-Mictaw inlier which suggests that this inlier was a positive relief during the history of the basin.

Session 5

Poster session 1

S05-1 POSTER

STRUCTURE AND STRATIGRAPHY IN THE WAGNER AND CONSAG BASINS, GULF OF CALIFORNIA, FROM SEISMIC REFLECTION

Hernández Pérez J. Antonio, González Escobar Mario y Martín Arturo

División de Ciencias de la Tierra, CICESE

mgonzale@cicese.mx

Seismic lines of multi-channel 2D reflection with a longitude of 415 km were processed and interpreted, with the objective to study structural and seismostratigraphy characteristics in the north of the Gulf of California. The region includes the zone of transition between Wagner and Consag basins.

The general configuration of the basins is controlled by 4 major faults, being these; Percebo, Santa Maria, Wagner Sur and Consag Sur, as well as a structural high that divides to both depocenters. We found that the Wagner and Consag basins are delimited by the faults Wagner Sur to the east and Consag Sur to the west, respectively. The Percebo fault borders the margin west of depocenter modern of the Wagner basin with strike of N100W and dip average of ~400 to the northeast. The Santa Maria fault is in center of the depocenter of the Wagner basin with an orientation of N190W and dip of ~400 to the west. The Consag Sur fault has a direction N140W, with dip of ~420 to the east with a length of 21 km. Finally, the Wagner Sur fault is the major structure to the orient of the study area, being almost parallel to Consag Sur fault with a length of ~86 km and direction N100W, with average of dip of 590 to the east.

The structural high observed delimits the north part of the Consag basin, with the south of the Wagner basin. In this sector it is not observed the presence of acoustic basement and/or intrusive body which is consistent with the reports of gravimetry and magnetometry for this area. This structural high this formed for an arrangement of faults of orientation NNE with vertical drop of little tens of meters and it is considered like a zone of transference that switching on the zones staggered of extension that they form Wagner and Consag basins. While the close south of the Consag basin tending to intercepting with the faults of direction NE of the Delfin Superior basin.

The three interpreted seismostratigraphy horizons are most of observed in the study region, showing a structural high in the border between both basins. The sediments in flanks of the structural high are cut by noticeable major faults with opposite falls followed of some strong reflectors within the basins. The Consag basin is more shallow and narrow; being ~2.5 times smaller than the Wagner basin and possibly it accommodates part of the right lateral shear of the limit of plates.

S05-2 POSTER

TEMPERATURE HISTORY OF THE ORANGE BASIN OBTAINED FROM CRUSTAL MODELS

Hirsch Katja¹, Scheck-Wenderoth Magdalena¹, Paton Douglas², van Wees Jan-Diederick³ y Cloetingh Sierd⁴

¹*GeoForschungsZentrum Potsdam*

²*School of Earth and Environment*

³*TNO*

⁴*VU University Amsterdam*

hirsch@gfz-potsdam.de

The Orange Basin off Southwest Africa is a sedimentary basin which developed subsequently to the break up of South America and Africa in the Late Jurassic. Cretaceous successions endured the tranquil drift and subsidence history of the basin nearly undisturbed and thus provide an ideal data base to study the interplay of lithospheric extension and subsidence.

To investigate the subsidence history of the basin in detail, several wells were backstripped. Backstripping yielded the observed tectonic subsidence to which forward models were constrained using a multiple-1D probabilistic tectonic heat flow modelling approach. Measured vitrinite reflectance data, which are a measure of the organic maturity of the sediments, are used as further constraints to the forward models. Probabilistic heat flow scenarios are calculated taking uncertainties from lithospheric stretching into account. The resulting basement heat flow history is a decisive parameter controlling the temperature history of the basin and in turn to the maturity of the deposited sediments.

This approach has been applied in 1D to data obtained from wells. In addition we want to go further and predict the basement heat flow history for undrilled areas. We generated an equidistant grid of synthetic wells using a structural model obtained from seismic data. Backstripping and forward modelling of these wells can predict the basement history and temperature evolution for areas where no well data are available and account for both temporal and spatial changes throughout the basin.

We discuss the geodynamic implications of the modelled basin evolution scenarios with special focus on temperature and heat flow variations and assess to which extent lithospheric stretching accounts for the observations.

S05-3 POSTER

BRITTLE MESOSTRUCTURAL KINEMATICS IN THE LAKE OKANAGAN FAULT ZONE: IMPLICATIONS FOR EOCENE AND YOUNGER DEFORMATION IN THE SOUTHERN CANADIAN CORDILLERA

Osadetz Kirk¹, Eyal Yehuda² y Feinstein Shimon²

¹*Geological Survey of Canada*

²*Ben Gurion University of the Negev*

kosadetz@nrcan.gc.ca

The Lake Okanagan Fault Zone (LOFZ) is a down to the west extensional detachment cut by steep normal faults in southern Canadian Cordillera. We focus on Eocene and younger mesostructural faulting, using fault and striation attitudes in combination with sense of motion indicators to analyze the regional deformation and stress history. Shallow ductile

shear progressively evolved to shallow brittle shear, followed by steep faulting as the structure was tectonically exhumed. This deformational style developed contemporaneously within a rheological domain and sequentially within a rock volume, as it thinned, cooled and was denuded. Locally the oldest faults are sub-horizontal and developed sub-parallel to mylonitic bands. The initial sub-horizontal faults are cut by a pervasive, sub-vertical, regional joint set (RJS) that is prominent in both Tertiary strata and plutons and which is parallel to Eocene dykes. The RJS is often reactivated by faulting. Neo-form faults are oriented favorably for brittle failure in paleostress fields like those inferred from the reactivated RJS faults. Meso-scale folds are consistent with fault kinematics. Most stations and faults record both an east-west (E-W) tension and a north-south (N-S) compression. The E-W tension orientation is like that of the ductile fabrics, Eocene dykes, and the general map-scale structure. Some stations and faults indicate an E-W compression, and others a N-S tension, or both. The stress history inferred from mesostructures is variable. Of the individual faults recording multiple strains, 42% indicate that E-W extension preceded N-S contraction, 23% indicate a transition from N-S contraction to E-W extension, 18% indicate either that E-W extension preceded E-W contraction, or that N-S contraction preceded N-S extension. In addition, 15% of the faults recording multiple strains indicate that E-W compression precedes any of E-W extension, N-S contraction or N-S extension, and 2% indicate that N-S contraction preceded E-W contraction. The observed E-W extension direction is not consistent with previously inferred NW-SE displacement estimates for the LOFZ. The kinematic link between ductile and brittle deformation suggests that the displacement, which remains undetermined, is complicated and accommodated on many ductile and brittle structures. Recent earthquake solutions indicate that southern Omineca Belt "feels" N-S compression and that current E-W tension occurs generally south of 49°N. The inferred paleostress record is dominated by ductile and brittle E-W tension, accompanied by a coeval E-W compression. Both these stress regimes have been overshadowed progressively by the currently dominant N-S compression. The apparent intermingling of the E-W compression with the other stresses supports the interpretation from other studies that thrust fault gouge radiometric ages in the southern Canadian Cordilleran Foreland Belt indicate Eocene and younger thrust motions of undetermined displacement.

S05-4 POSTER

CONTINENTAL RIFTING WITH FLAT MOHO

Thybo Hans, Nielsen Christoffer y Lyngsie Stig

*Department of Geography and Geology,
University of Copenhagen, Denmark*

thybo@geol.ku.dk

Rifting is a fundamental plate tectonic process that creates elongated depressions in the Earth's surface, which become filled with sedimentary and volcanic material, as it is presently observed at the Baikal, East African, Rhine Graben and Rio Grande Rift Zones. All rifting models predict Moho uplift due to crustal thinning, and reduced seismic velocity in the uppermost mantle due to decompression or heating from the Earth's interior. However, recently acquired data from the presently active Baikal Rift zone in Siberia and the failed Dniepr-Donets rift zone in Ukraine are examples where there is no Moho topography that can be related to the rifting process. Further, data from the Kenya Rift Zone shows sign of less Moho uplift than expected from the actual extension. At all these rift zones, we observe a localized zone in

the lower crust which has exceptionally high seismic velocity and is highly reflective. We suggest that rift related crustal thinning took place, but the expected Moho up-warp was compensated by magmatic intrusion in the lower crust at the high-velocity zone. This finding has significant implications for modelling of the evolution of sedimentary basins around rift structures.

S05-5 POSTER

SUBSIDENCE INDUCED BY MAGMATIC ACTIVITY

Thybo Hans y Sandrin Alessandro

*Department of Geography and Geology,
University of Copenhagen, Denmark*

thybo@geo.ku.dk

Significant topographic relief is identified in the basement surface of many sedimentary basins, albeit hidden by the sedimentary sequences. We discuss the possibility of formation of wide and deep sedimentary basins by thermal subsidence caused by magmatic intrusions into the crustal and mantle lithosphere. Magmatic intrusions may heat the lithosphere substantially independent of its origin, be it due to deep sources (e.g. mantle plumes) or decompression melting in high strain environments. Thermal expansion of the rocks of the lithosphere will cause uplift of the Earth's surface and erosion will bring the surface back to sea level. The subsequent cooling of the lithosphere creates the basin. Thermal sag basins are usually attributed to the heating of the crustal and mantle lithosphere due to extensional events, but here we focus on the role of heat brought into the crust and mantle lithosphere by magma. A characteristic feature of such basins is that relatively little faulting is expected in association with the subsidence. We find evidence from the Danish-Norwegian Basin in the North Sea area for significant regional magmatic intrusion into the crust during the Carboniferous to Permian. The subsequent Triassic subsidence shows almost no faulting, which indicates that the subsidence was not caused by tectonic stresses. We have studied two individual intrusions with estimated amounts of magmatic rocks of >40-100,000 km³. Assuming that other intrusions have similar volumes, the thermal relaxation to the magmatic event together with the isostatic response to the sedimentary load are sufficient to explain the observed subsidence. As such there is no need for invoking extensional stresses for explaining the Danish-Norwegian Basin.

S05-6 POSTER

CRUSTAL STRUCTURE OF THE OSLO GRABEN: PRELIMINARY RESULTS FROM MAGNUS-REX, CRUSTAL SCALE REFRACTION PROFILE

Thybo Hans¹, Stratford Wanda², Faleide Jan Inge³, Olesen Odleiv⁴ y Tryggvason Ari⁵

¹*Department of Geography and Geology,
University of Copenhagen, Denmark*

²*Department of Geography and Geology, University of Copenhagen*

³*Department of Geosciences, University of Oslo*

⁴*Geological survey of Norway*

⁵*Department of Earth Sciences, Uppsala University*

thybo@geo.ku.dk

A new crustal scale seismic profile was recorded in October, 2007, across the Oslo Graben as part of the Magnus-Rex

seismic project. This profile crosses east-west through the graben, extends to the west coast of Norway and 100 km east of the graben into Sweden. The Oslo line passes through the middle of the graben, through the region of lowest gravity anomaly and across the lowest gravity gradients at the margins. Single component seismographs were deployed along the line at 2 km spacing, except for a 120 km wide section across the graben where the instrument spacing was reduced to 750 metres. Seven shots of 100-400 kg charge size were fired along the Oslo line. Key phases observed on the shot gathers are: Pg arrivals with velocities of 6-6.4 km/s (all shot gathers); Pn phases from beneath western Norway and beneath the graben itself; strong PmP or lower crustal reflections at offsets greater than 50 km (all shot gathers). PmP reflections are characteristically different in and out of the graben with higher frequency, ringing reflections recorded to the west and lower frequency reflections recorded from beneath the graben. Preliminary results for the Oslo line show a Moho depth of around 35 km in western Norway that shallows to the east under the middle Oslo Graben. These results are in accord with the velocities and depths determined by the early refraction studies. Previous crustal models for the Oslo Graben, based on the interpretation of the gravity data, have inferred the 20 mgal positive gravity anomaly is due to a high-density mafic-ultramafic underplate at the base of the crust. This underplate would be the source zone for the differentiation of the Oslo igneous series. More recently, a different model has been inferred whereby the graben structure is made up of normal Baltica crust and the gravity anomalies are attributed to shallow, over-thrusted highdensity, rocks. The new seismic data presented here best concurs with the later model as no significant changes in Pg velocity are seen as waves enter the graben and no crustal first arrivals with velocities > 7 km/s, which might indicate underplating, are observed.

velocity. These basin share many characteristic in common with the intra-cratonic basins of Europe.

S05-7 POSTER

SEDIMENTARY BASIN EVOLUTION IN SOUTH ASIA: EXAMPLES FROM WESTERN CHINA

Mooney Walter D.

USGS, USA

mooney@usgs.gov

Northwest China contains a system of large sedimentary basins that include the Tarim, Qaidam, and Junggar. These basins are situated adjacent to the Tibetan Plateau and exhibit basements with contrasting evolutionary histories. Here we review the deep structure of these basins and their tectonic implications. The available active-source seismic profiles include: (1) a 1,400 km transect extending from the northern margin of the Tarim Basin to the eastern margin of the Qaidam Basin crossing the Altyn Tagh Range, (2) a 300 km transect extending from the northern to the southern margins of the Qaidam Basin, and (3) a 600 km transect extending from the northwestern to the southwestern margins of the Junggar Basin. The crustal structure of the Tarim Basin is interpreted as a typical stable continental platform. The seismic velocity boundaries between the felsic upper, intermediate middle, and mafic lower crust display clear divisions. Conversely, the Qaidam Basin, which lies at an elevation of ~3,000 m above sea level, is more similar to the soft deforming crust of the Tibetan Plateau. This crust is more felsic and lacks a high velocity mafic lower crust. Crustal structure of the Junggar basement includes a mix of oceanic materials and older blocks. Average crustal thicknesses are 55 km for the Tarim, 60 km for the Qaidam, and 50 km for the Junggar and the average seismic velocities are 6.0 km/s, 5.8 km/s, and 6.3 km/s (respectively). Of the three basins described, the Junggar is the thinnest and has the highest

Session 6

Volcano failure

Chairs:

Alessandro Tibaldi

Derek Rust

S06-1

GROWTH AND FAILURE OF VOLCANOES: A LESSON FROM NISYROS (GREECE) BY FIELD AND OFFSHORE DATA, AND ANALOGUE MODELLING

Tibaldi Alessandro¹, Papanikolaou Dimitri²,
Pasquarè Federico³ y Nomikou Paraskevi²

¹*Dipartimento di Scienze Geologiche e Geotecnologie, Università degli Studi di Milano Bicocca, Milano, Italy*

²*Department for Dynamic Tectonic and Applied Geology, University of Athens, Greece*

³*Dipartimento di Scienze Chimiche e Ambientali, Università degli Studi dell'Insubria, Como, Italy*

alexandros.tibaldi@unimib.it

We use new on-land and offshore structural data and scaled analogue models to analyse the structural pattern and evolution of Nisyros volcano (Greece). This volcano is characterised by the presence of a caldera structure and a complicated network of intracaldera and extracaldera faults, fractures and volcano-tectonic structures. We measured 157 faults that show dominant dip-slip normal motions along planes mainly striking NE-SW, NNE-SSW, and NNW-SSE. Inside the caldera, dykes, necks and morphometric parameters of volcanic domes, explosion craters and fumarole pits indicate the control by NE-striking discontinuities on magma and gas paths. The NNW- and NE-striking faults bound a major block that underwent repeated downthrow and uplift movements during the late Pleistocene-Holocene. Experiments with scaled models of caldera and two magma chambers indicate the formation of a hourglass-shaped fault pattern, as seen in plan view, with an asymmetric increase in the fault offset and a widening of the fault divergence towards the volcano flank. All these data suggest that regional fault tectonics and stress state strongly guided magma upwelling and the emplacement of volcanic centres, whereas periodical bulging due to the overpressure of a second magma chamber located northwest of the caldera combined with faulting due to tectonic stresses, can account for the overall deformation field. Moreover, our data demonstrate that a huge lateral collapse involved the SE flank of this volcano and also the submarine portion of the slope, producing a large debris avalanche deposit with a volume of about 1 km³. The magma-feeding system in the volcano, pre-dating and following the collapse, was influenced by the dominant NE-SW tectonic structures, which are perpendicular to the newly-recognised sector collapse. We suggest that the lateral magma pressure produced by repeated magma injections along tectonic discontinuities contributed to destabilise the volcano flanks. The occurrence of a pyroclastic deposit that mantled the scar left by the collapse suggests that a magma batch might have been injected inside the volcano and triggered the collapse. The lavas of the pre-collapse edifice have been deposited in alternating submarine and subaerial environments, suggesting that vertical movements might also be a major triggering mechanism for large lateral collapses.

S06-2

LONG-TERM EVOLUTION OF INDIVIDUAL VOLCANOES AND VOLCANIC SYSTEMS RECORDING LITHOSPHERIC PROCESSES. THE EXAMPLE OF THE CARPATHIAN-PANNONIAN REGION (CENTRAL-EASTERN EUROPE)

Szakacs Alexandru¹, Seghedi Ioan² y Pécskay Zoltán³

¹*Sapientia University, Dept. of Environmental Sciences*

²*Institute of Geodynamics, Romanian Academy, Bucharest, Romania*

³*Institute of Nuclear Research of the Hungarian Academy of Sciences, Debrecen, Hungary*

szakacs@sapientia.ro

Although the development of volcanic systems is generally acknowledged as one of the most meaningful consequences of lithospheric evolution, information on volcanism is still frequently omitted from regional geodynamic reconstructions and modeling. The present-day picture of active volcanism is a snapshot reflecting actual state of lithosphere and ongoing geodynamic processes of its respective occurrence areas. The volcanic history of a particular region may thus be viewed as a succession of such snapshots covering significant time intervals. The type, style and space-time distribution pattern of volcanism closely follows lithosphere evolution of geodynamically active areas. Individual long-lived composite volcanoes record intervals of lithospheric evolution in the order of 0.5-3 Ma. The accuracy of volcano history reconstruction depends on the resolution of dating techniques which is decreasing for progressively older volcanism, thus the suitability of individual volcano histories as recorders of lithospheric processes is apparently restricted to active or recent volcanoes. Major events – both constructive and destructive – of volcano evolution are well preserved in the geologic record and can be dated with convenient reliability so that a geodynamically significant “master-event- history” can be obtained. As a consequence, the applicability of long-lived individual volcano evolution in lithosphere process investigations can be extended back in time as far as current dating techniques are able to resolve their master-event-histories. Larger volcanic systems, including volcano fields, ranges/arc segments/arcs or entire arc – back-arc systems are suitable for longer times-span (in the order of up to x10 Ma) reconstructions of larger-scale lithosphere evolution in the light of volcanic evolution. Regional shifts of style, composition and petrogenesis of volcanism, as well as space-time migration of volcanic foci are relevant processes which can be interpreted in terms of lithospheric evolution.

The Carpathian-Pannonian Region (CPR) in Eastern Europe is a particularly suitable area to investigate and understand processes of lithospheric evolution recorded by products of volcanic activity at different time-scales. The large Calimani volcanic edifice (10.5-7 Ma) in the East Carpathians, with its complex history including edifice building and failure, shift of the focus of activity, caldera formation and post-caldera stage activity is a relevant example of long-term individual volcano evolution influenced by ongoing lithospheric processes related to lithosphere shortening, thickening, uplift and faulting. The ca. 160 km long Calimani-Gurghiu-Harghita segment of the Carpathian volcanic arc records a ca. 10 Ma long history (10.5-0.01 Ma) of unusual along-arc migration and gradual decrease in erupted magma volumes along with significant compositional changes at its south-eastern terminal sub-segment which makes it unique within the broader Carpathian-Pannonian system as a reflection of the particular geodynamic evolution of its related lithosphere segment. Finally, the ca. 21 Ma long story of volcanism (including felsic and intermediate calc-alkaline and alkaline volcanism) of the whole Carpathian-Pannonian

Region, as revealed by a radiometric age database of more than 2000 entries, displays a picture of four different space-time evolution patterns of volcanism reflecting a wide range of specific asthenosphere-lithosphere interaction processes such as a larger stationary mantle plume, episodic finger-like “baby plumes”, slab delamination, slab rollback and tearing.

S06-3

UNSTABLE VOLCANOES AT THE EASTERN MEXICAN VOLCANIC BELT, IMPLICATIONS FOR NON-MAGMATIC TRIGGERS

Carrasco-Núñez Gerardo¹, Díaz-Castellón Rodolfo¹, Siebert Lee², Hubbard Bernard³, Sheridan Michael⁴ y Rodríguez Sergio⁵

¹Centro de Geociencias, UNAM

²Smithsonian Institution, USA

³USGS, USA

⁴SUNY University at Buffalo, USA

⁵Instituto de Geología, UNAM

gerardoc@geociencias.unam.mx

The Eastern Mexican Volcanic Belt is characterized by the Citlaltépetl-Cofre de Perote volcanic chain, which forms an important topographic barrier separating the Altiplano (2,300 masl) from the Gulf Coastal Plain (1,300 masl). This high relief difference favors unstable conditions and the gravitational collapse of large volcanic edifices. The irregular configuration of the basement rocks, which slope towards the coast, is a dominant factor controlling the distribution of collapse events in all major volcanoes in the region, which collapsed preferentially towards the East. Catastrophic collapses from Citlaltépetl, Las Cumbres and, Cofre de Perote volcanoes produced voluminous debris avalanches and lahars that inundated the well-developed drainage that characterize the Coastal Plain, reaching up to more than 120 km from source. However, we have not found direct evidence of a magmatic component associated with the origin of these flank-collapses. Unstable conditions on the large volcanic edifices has been strongly favored by very intense hydrothermal alteration, abrupt topography and, intense fracturing. In addition to the highly irregular orientation of the sloping substrate, the reactivation of structures affecting the pre-volcanic basement during the Late Tertiary and, regional stress regime (principal horizontal stress is E-W at the southern part of the chain, and turning NE-SW to the north) may have played an important role in the preferential distribution of the avalanches. Non-magmatic factors such as: intense rain precipitation in the area and seismic activity (which has occurred in historical times) can be considered as the principal triggering mechanisms that caused flank collapse of large volcanic edifices in the Eastern Mexican Volcanic Belt. Assuming that non-magmatic unstable conditions of major volcanic edifices of the Eastern Mexican Volcanic Belt have been associated with catastrophic sector collapses in the past, recurrence of these events is very likely and can occur without warning.

S06-4

THE CALDERA DE MALPASO AND THE EL OCOTE IGIMBRITE, AGUASCALIENTES, MÉXICO

Nieto Obregón Jorge¹ y Aguirre Díaz Gerardo de Jesús²

¹Facultad de Ingeniería, UNAM

²Centro de Geociencias, UNAM

nieto@servidor.unam.mx

A new caldera is reported, west of the city of Aguascalientes, Mexico, where a voluminous pyroclastic volcanic sequence was deposited over a mesozoic basement, on a highly fractured and faulted volcano tectonic depression. This depression is truncated by younger normal faults of the Calvillo and Aguascalientes grabens. In the intracaldera facies, the El Ocote Ignimbrite fills the caldera depression, and consists of a very high grade reomorphic ignimbrite with lava-like features. The pyroclastic nature of this unit is demonstrated by the presence of a eutaxitic fabric with abundant mesoscopic elongated fiammes, and centimeter-size lithics rotated within the foliation. Devitrified glass shards and axiolites of collapsed pumices are observed under the microscope. The glass shard matrix is deformed by flow around rigid phenocrysts. Over the mesozoic basement, red beds intercalated with pyroclastic surge deposits and unwelded dense ash flows, poured over the area during a rapid sedimentation.

These units are covered by the tightly folded reomorphic ignimbrite. Younger rhyolitic domes occur in the center of the caldera, from which a sequence of unwelded ignimbrites of white yellowish color was generated. Finally to the west of the area andesitic feeder dykes produced flows that locally intrude and cover the older units. Normal faulting associated with Calvillo and Aguascalientes grabens facilitated the extrusion of these lavas.

The El Ocote Ignimbrite is reomorphic, i.e. it presents ductile deformation of hot pyroclastic material, forming folds of different styles (gentle, open, close, tight, isoclinal and sheath folds). Open folds are often formed from refolded foliation folds. Planar and linear features, such as foliation, axial planes, fold axis and elongation lineations, suggests deposition over an irregular surface, flowing in different directions, from various sources within and in the borders of the caldera.

The reomorphic ignimbrite is mainly distributed in the central portion of the caldera and although its thickness has not been quantified, it has more than 300 m in the southern border of the caldera in Sierra El Laurel. The extra caldera facies of this unit has thinner thicknesses, from 20 to 150 m, observed in the Mesa San José de Gracia, and to the south of Sierra El Laurel.

The area is affected by two types of faults of different ages: 1) volcano-tectonic faults, produced by caldera subsidence processes and; 2) tectonic faults of post caldera age, that truncate its western and eastern borders.

The caldera formed by the chaotic subsidence collapse of the magma chamber roof, in a piece meal manner, producing a style of volcano tectonic faulting in several stages and diverse orientations. The northern and southern borders are almost parallel, and are truncated by younger faults. This irregular shape of the volcano tectonic depression is better termed a Graben-Caldera (sensu: Aguirre-Díaz et al., 2007).

Session 7

Volcanism and geodynamics

Chairs:

Luis Delgado

Ioan Seguedi

S07-1

**BASEMENT CONTROL ON THE OCCURRENCE
OF RAPAKIVI GRANITE AND RELATED
LAVAS IN THE WESTERN UNITED STATES:
EVIDENCE FROM THE SUBVOLCANIC LITTLE
CHIEF STOCK, DEATH VALLEY CALIFORNIA**

Tormey Daniel
ENTRIX, Inc.
dtormey@entrix.com

The 10 m.y. Little Chief granite porphyry preserves the transition from volcanic to subvolcanic environments, and is spectacularly exposed over 28 km² and 1,920 meters of vertical relief in the Panamint Range bounding Death Valley, California. It was recently shown that rapakivi granites appear to be the plutonic equivalents of the relatively widespread, fluorine-rich, Cenozoic topaz rhyolites of the Western United States, both of which are emplaced in continental basement including extensive carbonates of the Proterozoic-Paleozoic miogeoclinal sequence. Study of the Little Chief indicates a strong basement control on the depth and style of crustal magma emplacement, with the limestone horizon appearing to act as either a rheological or density filter stalling magma ascent. In addition, the data suggests that the limestone influences both the development of distinctive feldspar zoning and elevated fluorine content similar to that seen in topaz rhyolites.

The Little Chief consists of two approximately coeval intrusive bodies and an eruptive vent. The granite has strongly zoned plagioclase, including rapakivi (sanidine rimmed by plagioclase) texture. The crystallization history suggests that the magma ascended through metamorphic basement until it reached the late Proterozoic Noonday Dolomite formation. At this depth, the vertical rise was diverted horizontally to form a laccolith-shaped body. By approximately 30 to 50 percent crystallization, the carbonate basement rocks began degassing and the magma shows extensive assimilation of country rock. The degassing caused extensive fracturing of the roof rock, further rise of the magma through the crust, emplacement of a dike swarm, and local eruption. The carbonates are less dense than the deeper metamorphic basement, and as such may have acted as a density filter stalling magma ascent. There may also be a rheological control on magma ascent by the carbonates as they appear to be structurally weaker and therefore allow lateral motion in the crust. Rapakivi-textured feldspars formed subsequent to the degassing; the texture appears to have formed both due to extensive assimilation of calcium from the carbonate basement rocks, and from depressurization after the degassing limestone fractured extensively allowing the magma to continue its rise through the crust.

The carbonates also impart to the magma a wide range in initial 87/86Sr, but limited variation in initial 143/144Nd, owing to their high Sr content but very low REE content. Many limestones are also rich in fluorine and therefore fluorine would also be enriched by carbonate assimilation. These attributes also characterize the widespread Cenozoic topaz rhyolites. Their occurrence on the carbonate miogeoclinal sequence and similarity to rapakivi granites suggest that carbonate basement may be a necessary condition to the formation of the topaz rhyolites.

S07-2

**CONTROLS ON EMPLACEMENT OF HYPABYSSAL
SHEETS: INSIGHTS FROM THE ERODED
THVERFELL VOLCANIC CENTRE IN ICELAND**

Rust Derek¹, Tibaldi Alessandro², Vezzoli Luigina³ y Pasquaré Federico³

¹University of Portsmouth, UK
²Università di Milano-Bicocca, Italy
³Università dell'Insubria, Italy
derek.rust@port.ac.uk

Fault geometry and kinematics indicate that two different tectonic regimes affected the late Pliocene volcanic succession around the Thverfell magmatic complex (Esja peninsula, SW Iceland). The older phase is characterized by sets of left-lateral, E-W to ESE-WNW faults and right-lateral, N-S to NE-SW faults; while the younger phase produced dip-slip, NNE-SSW striking extensional faults. Stress tensor determinations for the older regime indicate a horizontal, NE-SW to E-W maximum principal stress (σ_1) and a horizontal NW-SE to N-S minimum principal stress (σ_3); followed by a stress regime change to a vertical σ_1 and a WNW-ESE trending σ_3 . Structural-stratigraphic analyses of the eroded Thverfell magmatic complex indicate three main hypabyssal systems: (i) a centrally-dipping sheet swarm, elongated E-W in map view, (ii) a laccolith composed of a sequence of sills fed by E-W dykes, and (iii) NNE-SSW to NE-SW dykes offsetting the earlier intrusions. These data indicate a polyphase history of magma-tectonics interaction. Initially, excess pressure from an underlying magma chamber induced the emplacement of the centrally-dipping sheets; this was accompanied by magma upwelling along dykes that realigned to propagate as sills under the influence of stress and rheological barriers resulting from the lava overburden. In the final phase regional dykes were emplaced, linked to WNW-ESE rift extension.

S07-3

**GEOCHEMISTRY AND TECTONIC
SETTING OF THE EARLY CRETACEOUS
ZACATECAS VOLCANIC COMPLEX, MÉXICO**

Escalona Alcázar Felipe de Jesús¹, Delgado-Argote Luis A.¹, Velasco Tapia Fernando² y Nebel Oliver³

¹Departamento de Geología, CICESE
²Facultad de Ciencias de la Tierra, UANL
³Department of Petrology, Vrije Universiteit Amsterdam
papiasca@yahoo.com

The Guerrero terrane is a complex made up by Triassic to Early Cretaceous island arc, back arc and ocean floor lithologic assemblages. The Sierra de Zacatecas is interpreted to be one of the few exposures identified as fragments of the Guerrero terrane in central Mexico. There, the basement is not exposed and the lowermost stratigraphic unit is the Zacatecas Formation (ZF) composed of feldspathic and lithic wacke, mudstone, chert and discrete limestone lenses; basaltic lava flows, dikes and hydrothermal vent-like structures are also found. The contact with the overlying Las Pilas Volcanosedimentary Complex (LPVC) is gradual. The LPVC is composed of laccolith-shaped intrusions, massive and pillowed basaltic to andesitic lavas with interlayered feldspathic wacke and rare limestone.

U-Pb dating of detrital zircons from the feldspathic wackes of ZF and LPVC yield a minimum depositional age of ca. 132 Ma.

Harker diagrams of intrusive bodies having less than 49% silica do not show major differentiation, while the volcanic rocks trends can be explained by a process of fractional crystallization. All samples have positive Eu/Eu^* (0.34 to 0.43) suggesting plagioclase accumulation.

The REE patterns of lavas and intrusive rocks are parallel, showing a slight enrichment in LREE compared to MREE and HREE. The REE and trace elements patterns suggest an island arc association and the entire samples plot in the destructive plate margin field of the Th-Hf-Ta tectonomagmatic discrimination diagram.

We interpret from the field relationships that the igneous and sedimentary rocks belong to a volcanic complex that includes intra-arc or back-arc sedimentary facies. The most probable period of development of such complex is interpreted to be Early Cretaceous. Such period is intermediate between the Late Jurassic-Early Cretaceous ages reported in similar assemblages in Baja California and the Aptian-Albian ages reported in the State of Mexico and Guerrero.

S07-4

**ENVIRONMENT AND AGE OF EMPLACEMENT
OF PLUTONIC COMPLEXES FROM THE
SOUTHWESTERN MARGIN OF THE PENINSULAR
RANGES BATHOLITH, BAJA CALIFORNIA, MÉXICO**

Delgado-Argote Luis A.¹, Peña-Alonso Tomás A.¹, Weber Bodo¹,
Molina-Garza Roberto², Böhnel Harald² y Valencia Víctor³

¹*División Ciencias de la Tierra, CICESE*

²*Centro Geociencias, UNAM*

³*Dept. of Geosciences, U. of Arizona*

ldelgado@cicese.mx

Plutonic rocks belonging to three magmatic arcs crop out extensively in central Baja California peninsula. The oldest are in the western coast, they are M and I type and Jurassic in age. The Early Cretaceous plutons of the central part are I-type and, together with the Late Cretaceous eastern S-type plutons, form part of the Peninsular Ranges Batholith (PRB). The plutonic complexes from each region have characteristic dimensions, structures, petrologic features and environment of emplacement.

This work deals with the plutons of the central part, between 28o and 29oN, where the NNW trending Peninsular Ranges Batholith changes to a WNW orientation. In this region, it is proposed from a curve-density map of structures related to the emplacement of plutons, that the ridges are zones of higher rates of magma accumulation and that their axis can be correlated with magma flow direction. It is also suggested from field work that cortical discontinuities are occupied by magma that moves laterally at shallow depths. Main interpreted structures are fractures which parallels compositional zoning. The plutonic complexes are commonly formed of nested or concentric discrete bodies. Four of them were selected for U-Pb zircon separates dating and comparative analyses. From west to east: Punta Prieta (ca. 128 Ma), Nuevo Rosarito (ca. 108 Ma), El Mezquital (ca. 113 Ma) and La Rinconada (ca. 102 Ma). The complexes are enclosed by a sequence of metamorphosed sedimentary and volcanic interlayered rocks. With the exception of a ca. 151 Ma old sample from eastern Nuevo Rosarito, the age of tuffaceous sandstones from Punta Prieta, Nuevo Rosarito and SE Nuevo Rosarito, yield

ca. 140, 139.5 and 139 Ma, respectively. Around Punta Prieta, enclosing rocks are formed by a thick pile of andesitic lavas and breccias and fossiliferous limestone while, eastward Nuevo Rosarito, country rocks are dominantly volcanosedimentary.

According with the enclosing lithology and a WNW magmatic foliation and shearing, Punta Prieta is a plutonic complex distinct of the more than 40 km-long group of discrete complexes between Nuevo Rosarito-Marmolito-Mezquital-Rinconada. Such group is characterized by magmatic and tectonic foliation trending NNW in average; longitudinal fractures and dikes are oriented NW.

It is interpreted that the Cretaceous Punta Prieta plutonic complex is located near large volcanic structures dominated by andesitic lavas. The presence of other plutons near present surface is inferred from hydrothermally altered andesitic rocks defined as their roof. From the dated sandstone xenolith of Punta Prieta and the host tuffaceous sandstones from Nuevo Rosarito to La Rinconada ranging from Late Jurassic to Lower Cretaceous, we interpret that the plutonic and volcanic sequence was emplaced in and over the back arc of the Jurassic Volcanic Arc exposed in Cedros-Sierra San Andrés.

S07-5

**COMPARING TWO PLUTONS OF THE NUEVO ROSARITO
PLUTONIC COMPLEX, SOUTHERN PENINSULAR
RANGES BATHOLITH, BAJA CALIFORNIA, MÉXICO**

Peña-Alonso Tomás A., Delgado-Argote Luis A. y Weber Bodo

División de Ciencias de la Tierra, CICESE

alepena@cicese.mx

Near the southern limit of the Peninsular Ranges Batholith, in Baja California, Mexico El Sacrificio and Rosarito plutons are part of the Nuevo Rosarito Plutonic Complex (NRPC). Zircon separates from the Rosarito pluton yield a 108 +/- 2.2 Ma U-Pb age. El Sacrificio is a circular (~3 km diameter) gabbroic pluton characterized by the presence of up to 800 m² stoped blocks of the volcanosedimentary enclosing rocks. In contrast, Rosarito is a 6 km long NNW-SSE elliptical gabbro pluton. The host rocks of the NRPC are defined by NW-SE trending and sub-vertical dipping metamorphosed sedimentary and volcanic interlayered rocks. U-Pb ages of different lithologies of the country rocks range from the uppermost Jurassic to Lower Cretaceous. Some granitoid bodies can also be part of the enclosing lithology in El Sacrificio. Metamorphic facies range from low-grade greenschists to amphibolite, and structural fabrics range from penetrative schistosity to mylonitic textures. From the oldest to the youngest, both plutons experienced the emplacement of 2-px gabbro, 2-px diorite and different felsic bodies. Both plutons also show a similar mineralogy. The gabbroic rocks from El Sacrificio pluton exhibit coarse-grained cumulates in its western margin, and flow banding in its internal part that indicates stoping-related processes. Parallel to the regional structural trend, the gabbro from the Rosarito pluton show a NNW-SSE oriented and sub-vertical magmatic fabric. Contacts between diorite and gabbro can show jagged-like interfingering and sharp tabular structures; however, contacts between diorite and gabbro are sharp. Both magmatic and solid-state fabrics can be observed in the late felsic bodies. Orthogonal arranged shear planes filled with hydrothermal epidote are observed in all the intrusive units which are interpreted to be related to the emplacement of the felsic intrusives. Shearing analyses indicate dextral sense of movement along a NNW-SSE (343o/87o) nodal plane, which parallels the magmatic foliation in the gabbroic and felsic units of the Rosarito pluton.

Based on structural and textural features, we interpret that El Sacrificio pluton, where magmatic stoping is observed, and that Rosarito pluton, that evidence forcible intrusion, were emplaced in different crustal level probably under a regional extensional regime.

Session 8

**Lithosphere-asthenosphere
interactions, baby
plumes and paleostress**

Chairs:

Larissa Dobrzhinetskaya
Irina Artemieva

S08-1

RECYCLING OF NITROGEN AND BORON INTO EARTH'S INTERIOR THROUGH DEEP SUBDUCTION

Dobrzhinetskaya Larissa¹, Wirth Richard², Yang Jingsui³ y Green Harry¹¹University of California at Riverside, USA²GeoForschungsZentrum, Potsdam, Germany³Key Laboratory for Continental Dynamics, Institute of Geology, Beijing, China

larissa@ucr.edu

Nitrogen is a well known constituent of diamonds from both kimberlitic sources and ultrahigh-pressure metamorphic terranes related to continent-continent collisions. It was also described in ilmenite xenocrysts from African kimberlites. We have recently discovered nanometric inclusions of Boron Nitride and TiN ¹²C osbornite ¹²C in coesite associated with kyanite, FeTi alloy and OsIr alloy containing microdiamond inclusion; all are from massive chromitite of the mantle section of the Tibetan ophiolite. Both TiN and BN form bright-contrast particles in secondary-electron SEM images. Because EDS spectra of boron and nitrogen have severe overlaps with Ti L-lines, we have used EELS to confirm the presence of boron and nitrogen K-edges and to separate them from Ti L-lines. Electron diffraction data (TEM) identify the cubic boron nitride (c-BN) structure. TiN is stoichiometric (Ti=77.20wt%; N=22.80wt%) and has cubic symmetry, NaCl structure. NanoSIMS studies of osbornite show that its $\delta^{15}\text{N} = -10.4 \pm 3 \text{‰}$, what is a characteristic of mantle nitrogen known in many kimberlitic diamonds.

Because both nitrides are inclusions in coesite, high-PT conditions are required for their formation. We offer two hypotheses to explain their origin: *astroblesme* versus a mantle convection model. *Astroblesme* hypothesis is less favorable because there are not any evidence of impact microstructures in the host coesite and in the surrounding phases. We hypothesize that a small fragment of boron-rich Si-Al metasediments was subducted to mantle depth and due to mantle convection was brought to the mid-oceanic ridge to be trapped by chromitite at the bottom of lower horizons of the Tibetan ophiolite formation. This is unexpected occurrence for B-bearing metasediments. The finding of nitrides within chromitite of an ophiolite in combination with several high-pressure phases potentially has many profound implications for Earth. We now can be sure that within at least some ophiolites there is a solid component of rock from at least 300 km and probably from much deeper that accompanies the rock that partially melts and loses its *memory* of its deeper travels. Two major components of this old and deep *memory* are nitrides and evidence of very low oxygen fugacities. Does this *memory* in other ophiolites also include nitrides? If so, the geochemical community finally has access to (or the beginnings of access to) the missing N that has confounded understanding of this element for many years and the geophysical community may have firm evidence for one of the light alloying elements in the core.

S08-2

IN A SEARCH OF THE LITHOSPHERE-ASTHENOSPHERE BOUNDARY: A REVIEW

Artemieva Irina

Copenhagen University, Denmark

irina@geo.ku.dk

This paper reviews different definitions of the lithosphere and compares the estimates of the depth to the lithosphere-asthenosphere boundary as defined by seismic, thermal, electromagnetic, xenolith, and gravity data. While many of these definitions are based on remote measurements of different temperature-dependent physical properties of rocks, others reflect compositional variations in the upper mantle. In all cases, a caution should be made not only when comparing estimates coming from different techniques, but often when the same methods are implemented to calculate the lithospheric thickness and the depth of the lithosphere-asthenosphere transition.

S08-3

THE ROLE OF FINGER-LIKE BABY PLUMES IN THE GENESIS OF MIOCENE-PLIOCENE ALKALIC BASALTIC VOLCANIC FIELDS FROM THE WESTERN PART OF THE CARPATHIAN – PANNONIAN REGION, CENTRAL EUROPE

Seghedi Ioan¹, Szakacs Alexandru², Kadosa Balogh³ y Pécskay Zoltán³¹Institute of Geodynamics, Romania²Sapientia University, Romania³Institute of Nuclear Research of the Hungarian Academy of Sciences, Hungary

seghedi@geodin.ro

Several quasi-circular alkalic basaltic volcanic fields (~ 30 – 40 km in diameter), composed by individual volcanic centers are present in the western part of the Carpathian - Pannonian region known as the Little Hungarian Plain, Styrian Basin and Balaton Highland. Each volcanic center has been emplaced as a single magma pulse in a short time interval, as proved by K-Ar dating. The successive eruptions of individual monogenetic volcanoes cover an overall interval of volcanic activity between ~ 6-2 Ma ago in each volcanic field, which apparently suggests a quite continuous activity.

Major and trace element data normalized to primitive mantle values corresponding to individual volcanoes prove that besides their different age, they also have different compositions. Several rock groups have been separated for the Little Hungarian Plain (1, 2, 3) and Styrian Basin (2, 3, 4), while the Balaton Highland resemble, as a whole, the 3-rd group of the former areas. The first group, with minor troughs or spikes of the representative trace element distribution spectrum, although sometimes with greater depletion of heavy rare earth elements (HREE), is similar to the average OIB pattern, suggesting an asthenospheric origin. The second group has a significant and sometimes variable enrichment in incompatible elements (large ion lithophile elements-LILE), light rare earth elements (LREE), high Nb, along with a significant relative depletion of K; they appear characteristic for an enriched lithosphere. The third group presents an enriched pattern of LILE, including LREE, with variable enrichment in LILE. (i.e. Ba and Pb and sometimes Sr) and variable depletion of HREE (Zr, P and Ti). The forth

group shows characteristic variable negative Nb, REE, and P-depletion along with positive spikes of Ba, and strong positive K and Pb anomalies, similar to calc-alkaline basalts, suggesting the involvement of subduction-derived fluids. These unusual dissimilar geochemical characteristics, beside isotopic data, are interpreted as corresponding to different magma sources since no obvious fractionation processes can be proved.

The most plausible assumption for generation of these quasi-circular volcanic fields, complex from the geochemical and isotopic point of view, is the presence of mantle plumes. Small-scale "baby plumes" with a finger-like geometry and various compositional characteristics are able to bring up high thermal anomalies at the base of the lithosphere to trigger the generation of alkalic basaltic magma in an extensional environment. An upwelling asthenospheric plume at the base of the lithosphere by ~4% partial melting may generate the earlier volcanic rocks (first group); next, 1-2 % melting of an amphibole-bearing lithospheric mantle due to plume interaction (second group) or melting (2-4 %) of slightly (third group) or strongly affected (fourth group) by subduction-derived fluids lower lithosphere/upper asthenosphere gave rise to the present characteristic for each volcanic field and volcanic centre within.

S08-4

MICROTECTONIC ANALYSIS OF THE NORTHERN SLOPE OF ANCESTRAL MOUNT BAO, PHILIPPINES

Lagmay Alfredo Mahar Francisco¹ y Caranto Geoffrey²

¹National Institute of Geological Sciences, University of the Philippines

²Philippine National Oil Company Energy Development Corporation

mlagmay@nigs.upd.edu.ph, amfal2@yahoo.com

Ancestral Mount Bao (AMB) is an eroded stratovolcano, overlying the Philippine Fault in Leyte Island, Philippines. It is host to the Tongonan Geothermal Power Plant, which has an installed capacity of 700 MW. Recent microtectonic analysis of the northern slope of AMB shows a tectonic grain that mimics structures observed in analogue models traversed by strike-slip faults. Map views of the distribution of compressional and extensional structures in the eroded northern slope of the AMB provide a good analogue to experimental results not readily observed in active volcanoes.

S08-5

LATE CENOZOIC AND MODERN STRESS FIELDS IN THE WESTERN FARs (IRAN)

Lacombe Olivier, Mouthereau Frédéric y Amrouch Khalid

Université Pierre et Marie Curie, Paris

olivier.lacombe@upmc.fr

The Zagros belt results from the collision between Arabia and Central Iran, beginning in Miocene times and continuing today. GPS studies suggest that about 1/3 of the Arabia-Eurasia shortening (~7 mm yr⁻¹) is taken up in the Zagros. The belt was built by folding of a 6-8 km thick Phanerozoic cover detached from the Precambrian basement by the 1-2 km thick early Cambrian Hormuz salt layer; the basement is also involved in the collisional shortening.

The inversion of focal mechanisms of basement (and of few cover) earthquakes with small to moderate magnitudes shows a consistent N020°-030° compression with a low ratio between differential stresses. This regime accounts for the combination of strike-slip and thrust-type focal mechanisms through likely s2/s3 permutations whatever their magnitudes and focal depths; it is in good agreement with the pattern and the kinematics of active faults.

Analysis of striated faults reveals two successive late Cenozoic regional compressional trends, NE-SW then N025°. The NE-SW compression can be interpreted in terms of either stress deviations or block rotations in relation to right-lateral transcurrent faults. Analysis of calcite twinning in the ZSFB also yields a late Neogene reverse-strike slip stress regime with a 025° directed compression which prevailed mainly after folding. AMS studies indicate that Paleocene carbonates recorded a N47°-directed layer-parallel shortening (LPS) probably during folding in the High Zagros Belt, while Mio-Pliocene clastics recorded the N38° LPS related to Mio-Pliocene detachment folding in the ZSFB.

Calcite twinning paleopiezometry reveals an unexpected low level and first-order homogeneity of cover differential stresses across the ZSFB. In the Fars, seismicity is of low magnitude and occurs mainly in the basement, while the cover is almost devoid of large thrusts and mainly earthquake deficient. In addition to the low thickness of the seismogenic layer which is too thin to generate large earthquakes which cannot propagate upwards due to the salt layer, we suggest that the strata of the detached cover are buckling while internally deforming through diffusion-mass transfer and calcite twinning; these viscous-plastic creep mechanisms help to relieve stresses in the cover, keeping the stress level generally below the frictional yield required for large-scale faulting and therefore lowering its seismogenic potential.

The late Neogene 025° compressional trend is coaxial with the geodetic shortening axis, and nearly parallel to the seismic shortening axis (N010°). Long-term calcite twin and fault slip data and short-term earthquake and GPS data are therefore consistent with the idea that the regional compression remained approximately constant in space (across the Zagros collision zone) and time (during the late Neogene, since ~5 Ma), and that the Arabia-Eurasia convergence has been accommodated by both across-strike shortening and strike-slip faulting throughout the cover and the basement.

The agreement of the late Neogene stress pattern in the cover with the current stress field determined from the focal mechanisms of basement earthquakes interestingly suggests that the Hormuz salt decollement poorly decouples basement and cover stress fields, although the GPS strain rate in the cover is much higher than the seismic strain rate in the basement.

Session 9

Poster session 2

S09-1 POSTER

**COMPOSITIONAL HETEROGENEITY
OF THE CONTINENTAL UPPER
MANTLE HIDDEN IN SEISMIC MODELS**

Artemieva Irina

Copenhagen University, Denmark

irina@geo.ku.dk

Global seismic tomography models as well as mantle gravity anomalies reflect large-scale compositional variations in the mantle; however they are substantially masked by temperature anomalies. Data on the thermal regime of stable continental lithosphere provides an exceptional information on lithospheric properties as it permits to separate thermal and non-thermal effects in global geophysical models. Global surface-wave (Shapiro and Ritzwoller, 2002) and body-wave (Grand, 2002) seismic tomography models are analyzed jointly with thermal model for the upper 250 km of the continental mantle. Both seismic and thermal models for the continental upper mantle outline the same regions of thick continental lithosphere and indicates large variations in lithospheric thickness on the continents. Thermal model is used next to calculate "synthetic" model of seismic velocities at depths between 50 and 200 km: based on laboratory data, mantle temperatures are converted into velocities with account for anelasticity effects. Significant difference between "synthetic" and observed seismic velocities can be attributed to large-scale compositional and structural heterogeneity of the continental upper mantle. In agreement with xenolith data, strong mantle depletion is clearly seen for all of the cratons; however it shows strong lateral variations in the amplitude (Artemieva, Lithos, in press). The results are compared with the residual mantle gravity anomalies, which represent compositional density anomalies in continental lithospheric mantle after the effect of thermal expansion being excluded (Kaban et al., EPSL, 2003).

S09-2 POSTER

**OBSERVATIONS OF SEISMIC ANISOTROPY IN THE
GULF OF CALIFORNIA REGION AS EVIDENCE OF
LITHOSPHERE-ASTENOSPHERE INTERACTION**

Obrebski Mathias¹ y Castro Raúl²

¹*Institut de Physique du Globe de Paris*

²*División de Ciencias de la Tierra, CICESE*

obrebski@ipgp.jussieu.fr

New observations of S-wave splitting (SWS) in the Gulf of California region using SKS waves are combined with teleseismic receiver function observations, reported previously by Obrebski and Castro (2008), to infer possible lithosphere-asthenosphere interaction in this region.

We extended the analysis of Obrebski et al. (2006) and Van Benthem et al. (2008) who reported the first SWS observations in northern and southern Gulf of California region, respectively, using SKS waves. To obtain a robust characterization of seismic anisotropy at stations in the southern region of the Gulf of California we complemented our dataset including new splitting observations of S waves from intermediate to deep events. We also extended our analysis using records from the North Baja Transect (NBT) (Astiz et al., 1998), an east-west transect deployed at ~31° latitude between 1997 and 1998.

The region under study encompasses three structural domains defined by Stock et al. (1991) that divide the northern and central Baja California Peninsula (BCP) into the Transpeninsular Strike-Slip Province (TSSP), north of the Agua Blanca fault, and the Stable Central Peninsula (SCP) south of it. The third domain, located east of the above two, is the Gulf Extensional Province (GEP).

We found that the SWS fast direction is consistent with the results obtained by Obrebski et al. (2006) on the northern BCP and the E-W pattern reported farther north along the former trench in southwestern USA (Ozalaybey and Savage, 1995; Polet and Kanamori, 2002). The new results show that the fast direction abruptly changes toward the GEP, where it aligns with the trend of the transtensional rift. This rapid change in the anisotropy pattern is well resolved along parallel 31° using the data of the NBT transect and is geographically consistent with the limit between the SCP and the GEP provinces. In the eastern GEP, the fast direction is consistent with Miocene extension indicated by geologic features, although modern flow in asthenosphere conducted by the North American plate motion also satisfies this pattern, as proposed earlier by Obrebski et al. (2006) and van Benthem et al. (2006).

The results obtained from the receiver function analysis indicate that the three structural provinces studied have anisotropic characteristics markedly different and are the result of different kinds of lithosphere-asthenosphere interactions.

S09-3 POSTER

**SEISMIC ANISOTROPY OF THE CRUST AND UPPER
MANTLE BENEATH EAST AFRICA FROM JOINT
INVERSION OF SKS AND P RECEIVER FUNCTIONS**

Obrebski Mathias¹, Kiselev Sergey²,
Montagner Jean-Paul¹ y Vinnik Lev²

¹*Institut de Physique du Globe de Paris, France*

²*Institute of physics of the Earth, Moscow, Russia*

obrebski@ipgp.jussieu.fr

The analysis of the crust and upper mantle anisotropy revealed by seismic waves provides an unique way to obtain constraints on the lithospheric strain state and on the geometry of the asthenospheric flow. Previous studies of upper mantle anisotropy around the East African Rift relied either on splitting of SKS types waves or on surface wave tomography. Nevertheless, these approaches yield rather poor vertical and lateral resolution, respectively. Therefore fast 3D variations expected around a plate boundary may have not been detected. Recent improvements in the methodology have shown that high lateral and vertical resolutions are achieved by performing joint inversion of both receiver functions and SKS waveforms. Our preliminary results at permanent stations ATD, FURI and KMBO are encouraging. Unambiguous evidences of splitting have been detected in SKS waves, in agreement with previous similar studies in this region. On the other hand, the waveform of the Q (Sv) and T (Sh) receiver functions exhibit azimuthal variations that are dominantly produced by anisotropy, as indicated by azimuthal filtering.

S09-4 POSTER

**PERMIAN RHYOLITIC VOLCANISM IN THE
SIRINIA BASIN (SE ROMANIA-EASTERN
EUROPE) - VOLCANOLOGICAL FEATURES**

Seghedi Ioan

Institute of Geodynamics, Romania

seghedi@geodin.ro

Extensive volcanic activity characterizes the lacustrine Sirinia Basin during Lower Permian times. The intracontinental basin lying on the Danubian metamorphic units in the south westernmost part of the Carpathians (SE Romania) is oriented N-S, as affected by Alpine tectonic movements. It was a result of extensional tectonics that started with mollase type sediment accumulation.

Permian volcanic activity is entirely acid (rhyolitic) and volcanologically very complex. The volcanic area in spite of folding processes associated to Alpine tectogenesis is well preserved and encompasses a mountain area which rises up to 600m above the surroundings and has an approximate dimensions of 6 x 10 km. Permian volcanic deposits are nested toward east on top of Carboniferous detritic sediments, including coal and basaltic volcanic rocks.

Permian volcanism has been formed most likely as the result of intrusion along a dyke system of a rhyolitic magma body underneath. Initial subaqueous dome forming processes led to the generation at their margins of hyaloclastic breccias that turn unstable forming marginally turbiditic hyaloclastite aprons. Raising to shallower waters and then to subaerial the volcanic activity turned progressively to be highly explosive, generating phreatomagmatic eruptions that formed probably several craters, however not possible to be actually documented. The result of this activity is most impressive, draping the former morphology represented by terrigenous deposits and hyaloclastic domes and their products with a thick sequence of various deposits represented by proximal pyroclastic flow (dominantly non-welded and welded ignimbrites), pyroclastic surge and fall out rich in accretionary lapilli (with rare impact ballistic structures). The deposition was dominantly in the subaqueous environment, as suggested by the intensive diagenetic processes that changed the ash and glassy pumices in a green greasy secondary mineral or aggregate of minerals. Rare thick welded pumice and lithic rich ignimbrite deposits may suggest proximity of the vent area. At the distal, marginal part of the volcanic area the epiclastic, mostly lahar deposits are dominating, sometimes including layers up to meter size of fallout deposits with accretionary lapilli, that suggests their contemporaneous formation. The end of volcanic activity was effusive subaerial and several domes have been generated, the most imposing being the Trescovăþ dome situated in the central part of the volcanic area. Columnar jointing and cm size flow bending, sometimes suggesting turbulent flow is characteristic.

S09-5 POSTER

**ATTENUATION AND SEISMIC TOMOGRAPHY
STUDIES IN THE TRES VIRGENES VOLCANIC AND
GEOTHERMAL REGION, BAJA CALIFORNIA SUR, MÉXICO**

Wong Victor

División de Ciencias de la Tierra, CICESE

vwong@cicese.mx

We analyzed the spatial distribution of the seismicity recorded during October of 1993 at the Tres Virgenes volcanic and geothermal region, Baja California Sur. As a first result, it was determined that most of the seismic activity occurred at the Caldera El Aguajito and along the La Virgen fault. Focal depths determined for 85 % of the located events range from 3 to 7 km. We also estimated quality factors from coda waves (Q_c) and from P (Q_p) and S (Q_s) waves using a single-scattering attenuation model and the spectral ratio method, respectively, in the frequency range from 4 to 24 Hz. The values of Q_c at six, out of seven analyzed stations, showed quite similar trends at all frequencies. The seventh station (E1), located in a densely fractured area with hydrothermal manifestations, showed a trend that differs, in the low frequency range, from the rest of the stations. With a relation of the form $Q_c(f) = Q_0 f^h$ and data from the six stations having similar Q_c trends, we obtained $Q_c(f) = (50.0 \pm 3.0) f^{(0.65 \pm 0.20)}$ for the entire region. At the station E1, Q_c may be approximated by $Q_c(f) = (3.0 \pm 0.5) f^{(1.48 \pm 0.06)}$. From the body wave attenuation analysis, low values of Q_p and Q_s were determined. At all frequencies considered, the P wave attenuation was stronger than the S wave attenuation, suggesting a partially fluid saturated upper crust in the region. It was found that the frequency dependence of Q may be approximated by $Q_p(f) = (4.0 \pm 3.0) f^{(0.97 \pm 0.29)}$ and $Q_s(f) = (10.0 \pm 3.5) f^{(1.04 \pm 0.14)}$ for P and S waves, respectively, showing that Q_p and Q_s increase with frequency, in the same manner as Q_c does.

A simultaneous inversion of hypocenter and seismic velocity structure was also performed in a zone with volume $20 \times 24 \times 10 \text{ km}^3$ that includes the Tres Virgenes volcanic complex. Low velocity zones we determined at the south flank of the La Virgen volcano and at the south portion of the Caldera El Aguajito. One of this low velocity zones is located at the El Azufre Canyon area and on the hydrothermal zone. In the zone of the volcanoes the determined velocities are uniform both horizontally and vertically, suggesting quite similar velocity structure with depths larger than 8 km. The larger lateral velocity variations, which are observed up to 7-km depth, were associated with the El Azufre Canyon. The velocity variations that were determined within the inversion volume could be, among other reasons, due to effects of the inhomogeneous volcanic cover, the fractured granitic basement, the high temperatures in the volcanic zones and the fluid content of fractures in the geothermal zone.

Session 10

Basin processes and case studies

Chairs:

Magdalena Scheck-Wenderoth

Hans Thybo

S10-1

THERMO-MECHANICAL MODELS FOR BASIN (DE)FORMATION

Cloetingh Sierd, van Wees Jan-Diederik y Beekman Fred

VU University, The Netherlands

sierd.cloetingh@falw.vu.nl

Polyphase extensional and compressional reactivation of basins is a common feature in basin evolution. To differentiate between the different modes of basin formation and reactivation of passive margins and extensional basins, the development of innovative combinations of numerical and analogue modeling techniques is key. In this paper we present an overview of our advancement developing and applying analogue and numerical thermo-mechanical models to quantitatively assess the interplay of lithosphere dynamics and basin (de)formation.

Field studies of kinematic indicators and numerical modeling of present-day and paleo-stress fields in selected areas have yielded new constraints on the causes and the expression of intraplate stress fields in the lithosphere, driving basin (de)formation. Temporal and spatial variation in the level and magnitude of intraplate stress have a strong impact on the record of vertical motions in sedimentary basins. Over the last few years increasing attention has been directed to this topic advancing our understanding of the relationship between changes in plate motions, plate-interaction and the evolution of rifted basins.

The actual basin response to intraplate stress is strongly affected by the rheological structure of the underlying lithosphere, the basin geometry, fault dynamics and interplay with surface processes.

Integrated basin studies show that rheological layering and strength of the lithosphere plays an important role in the spatial and temporal distribution of stress-induced vertical motions, varying from subtle faulting to basin reactivation and large wavelength patterns of lithospheric folding, demonstrating that sedimentary basins are sensitive recorders to the intraplate stress field. The long lasting memory of the lithosphere, in terms of lithospheric scale weak zones, appears to play a far more important role in basin formation and reactivation than hitherto assumed. A better understanding of the 3-D linkage between basin formation and basin reactivation is, therefore, an essential step in research that aims at linking lithospheric forcing and upper mantle dynamics to crustal vertical motions, and their effect on sedimentary systems and heat flow.

Vertical motions in basins can become strongly enhanced, through coupled processes of surface erosion/sedimentation and lower crustal flow. Furthermore patterns of active thermal attenuation by mantle plumes can cause a significant spatial and modal redistribution of intraplate deformation, as a result of changing patterns in lithospheric strength and rheological layering.

Novel insights from numerical and analogue modeling aid in quantitative assessment of basin history and shed new light on tectonic interpretation, providing helpful constraints for basin exploration, including understanding and predicting vertical motions (eroded sedimentation record), source fill relationships, and heat flow.

S10-2

INTRACRATONIC BASINS: ROLE OF MANTLE DYNAMICS AND METASOMATISM

Artemieva Irina

Copenhagen University, Denmark

irina@geo.ku.dk

High topography of cratons is commonly attributed to depleted, low-density composition of the cratonic lithospheric mantle. However, most of the Archean-early Proterozoic East European Platform (EEP), and especially its southern part, is covered by an unusually thick (ca. 3 km) cover of sediments. Furthermore, most of the East European Craton lacks surface topography, while the topography of its basement exceeds 20 km, the amplitude of topography undulations at the crustal base reaches almost 30 km with an amazing amplitude of ca. 50 km in variation in the thickness of the consolidated crust, and the amplitude of topography variations at the lithosphere-asthenosphere boundary exceeds 200 km. This paper examines the relative roles of the crust, the subcrustal lithosphere, and the dynamic support of the sublithospheric mantle in maintaining surface topography, using regional seismic data on the structure of the consolidated crust and the sedimentary cover, and thermal and large-scale seismic tomography data on the structure of the lithospheric mantle. Negative residual topography beneath the Archean-Paleoproterozoic craton (-1-2 km) indicates either significantly smaller density deficit in their subcrustal lithosphere than predicted by petrologic data or the presence of a strong downwelling in the mantle (Artemieva, Global and Planet. Change, 2007). In the former case, a possibility of a compositional subsidence of the EEP in Paleozoic as a response to Devonian rifting at its southern margins cannot be ruled out. Phanerozoic rifting could cause a density increase of the depleted cratonic lithospheric mantle due to an intrusion of Fe-rich basaltic melts and thus can be responsible not only for subsidence due to thermal relaxation, but also for compositional subsidence (Artemieva, EPSL, 2003). The conclusions are strongly supported by the results of gravity modeling (Kaban et al., EPSL, 2003): residual mantle gravity anomalies, which represent compositional density anomalies in continental lithospheric mantle after the effect of thermal expansion being excluded, show significant increase in mantle density from the Baltic Shield to the southern parts of the EEP.

S10-3

COMPARING DIFFERENT STYLES OF SEDIMENTARY BASINS IN THE BARENTS SEA

Faleide Jan Inge¹, Planke Sverre² y Team PETROBAR¹Department of Geosciences, University of Oslo²Volcanic Basin Petroleum Research

j.i.faleide@geo.uio.no

The Barents Sea comprises a wide range of sedimentary basin architectures that formed in response to different geological processes. In particular there are major differences between the western and eastern Barents Sea.

The eastern Barents Sea is underlain by a wide (300-400 km) and deep (15-20 km) sedimentary basin that extends for more than 1000 km in a north-south direction. The basin formed by rapid subsidence in Late Permian-Early Triassic times. There are few

signs of faulting associated with basin formation and it does not look like typical rift basins.

There is a clear spatial correlation between the deep East Barents Sea Basin and the thickness of a high-velocity body in the upper mantle, and there is a temporal link between the main phase of basin formation and Siberian Traps magmatism. However, the links between the shallow and deep structure and any regional effects of the igneous activity are not well understood.

The deep East Barents Sea Basin was filled by thick Triassic sediments prograding westwards from uplifted source area in the SE (Urals). Subsidence analysis assuming crustal stretching/thinning as the main driving force for sedimentary basin formation implies large Beta-values and a relatively hot basin scenario. However, taking into account the dimensions of the broad sag basin and the general lack of faulting it is not obvious whether this is a valid assumption. Alternatively, we are studying the role of phase transitions in the crust and upper mantle and how they could have contributed to subsidence in a colder basin scenario.

In the western Barents Sea we find more typical rift basins formed in response to at least three major post-Caledonian rift phases: Carboniferous, Late Jurassic-Early Cretaceous, and Late Cretaceous-early Paleogene. The rifting activity migrated westwards through successive tectonic phases. Carboniferous rifting affected the entire western Barents Sea and gave rise to NE-SW to N-S trending horst and graben structures following a Caledonian basement grain. Late Jurassic-Early Cretaceous oblique extension in the deep SW Barents Sea basins was linked to the North Atlantic-Arctic plate tectonic evolution. A Late Cretaceous-Early Paleogene mega-shear system along the western Barents Sea-Svalbard margin (De Geer Zone) linked rifting, breakup and initial opening of the Norwegian-Greenland Sea and the Arctic Eurasia Basin.

Most Barents Sea basins have also been affected by regional magmatism, compressional deformation and inversion and/or late uplift and erosion. These overprinting processes may have had important implications for the basin evolution and the petroleum systems.

The different basin architectures and development are compared and discussed in relation to timing, deep crustal and upper mantle structures, and histories of vertical motion, basin filling and temperature.

S10-4

FLEXURE OF THE EURASIAN PLATE, LITHOSPHERIC BULGE AND DEVELOPMENT OF THE WESTERN FORELAND BASIN OF TAIWAN

Lacombe Olivier¹, Mouthereau Frederic¹ y Tensi Julien²

¹Université Pierre et Marie Curie, Paris

²AREVA

olivier.lacombe@upmc.fr

The Taiwan orogen results from the Plio-Quaternary oblique collision of the Paleogene Chinese irregular continental margin with the Luzon arc belonging to the Philippine Sea plate. The flexural response of the Chinese continental margin to orogenic loading, including timing and origin of the lithospheric bulge and development of the western foreland basin was investigated using subsidence patterns derived from well data and two-dimensional

geometric and numerical flexural modelling of a purely elastic plate.

Reconstructions of the forebulge and basin evolution since Middle Miocene place constraints on plate strength and geological context. Modelling suggests that the initiation of the flexure in the West Taiwan Basin occurred at ca.12.5-8.6 Ma, a good fit being obtained for T_e of 10-20 km, consistent with earlier studies. During 5- 6 my, the growth of the bulge was static and associated with increasing plate curvature. Then, at 3-4 Ma the bulge migrated forelandward within the West Taiwan Basin in relation to the migration of the load and the increase in plate curvature. We suggest that flexurally-controlled extension has reactivated some of the inherited Palaeogene normal faults of the Chinese continental margin, especially where pre-orogenic extensional basins exist, e.g. in the Tainan Basin. The passage of the forebulge at 12.5 Ma into an inherited weaker portion of the Chinese margin where pre-orogenic extensional basins occur produced an increase in plate curvature and renewed extension, leading to enhancement of the bulge uplift and to its localization for a prolonged period of time, i.e., without significant propagation forelandward. Taking into account the age of the flexure initiation and plate convergence rates, we infer that the load might not be related to the arc-continent collision, and that the deflection of the Chinese margin in the middle Miocene could be better explained by obduction of part of the South China Sea, as already proposed by some authors. It is not before 3-4 Ma that the bulge and the load propagated forelandward in association with the development of the Taiwan arc-continent collision.

In addition to the presence of inherited weaker parts of the lithosphere and mechanical yielding, along-strike variations in the development of the forebulge and the flexural deflection in the West Taiwan Basin may also be explained by the shape and the inherited basement topography of the continental margin and its obliquity with respect to the plate convergence and thus to the migration of the orogenic wedge.

These results finally provide new insights on the early stages of the Taiwan orogeny.

S10-5

THE SINU ACCRETIONARY PRISM (COLUMBIA) SHORTENING/GRAVITY TECTONICS INTERACTION PROCESSES FROM ANALOGUE MODELLING

Ellouz-Zimmermann Nadine¹, Deville Eric¹ y Benguigui Amran^{1 y 2}

¹Institut Français du Pétrole, France

²PDVSA, Venezuela

nadine.ellouz@ifp.fr

The Sinu accretionary prism (NW Columbia) results from the oblique subduction since Late Cretaceous times of the oceanic Caribbean plate below the south American one. The active part of the tectonic accretionary prism developed West to Northwestward, and constitutes the frontal part of the system, west of the San Jacinto Fold-and-Thrust Belt. The trench and the prism were progressively filled through time by erosion products conveyed either by Proto-Magdalena River (since Paleogene times), or by Sinu and Atrato Rivers (from the south), and the NE migrating Magdalena River-Delta during Cenozoic times.

The overall prism was analyzed and its evolution is presented in three major steps, based on fault activity pattern and the relationships with paleostress and sedimentary loading through time.

The main characteristic on the present-day morphology of the prism is a major indentation of the front illustrated by an important deformation style from North to South. This along-strike structural variation is expressed by: (1) a narrow prism in the southern part (close to Panama prism), showing back-thrusting processes at the front, (2) a large development of the prism in the central part with a frontal propagation of the thrusting, coeval with coupled argilokinetic and normal faulting processes (3) a narrow northern part, where the deformation is concentrated on the rejuvenation of inner thrusts, and where no deformation is observed in the area of the paleo-front.

During Upper Miocene to Pliocene time, in the central part of the prism, a huge input of sediment conveyed by the proto Magdalena River (coming from the southeast) where deposited behind and above the front. The rapid and concentrated loading observed in the central part of the prism generated the local "freezing" of the compressive units and the development of overpressure cells at depth. Mud diapirs and volcanoes have been described along seismic lines close to the shelf edge, and outlined these processes where combined regional shortening and high sedimentary rate induced overpressure regime at depth.

During Oligo-Miocene times, the prism developed over an irregular basement resulting from the thickening of the basal sequence (Cretaceous to E. Paleogene). At that time the structure of the prism is more or less cylindrical.

Analogue experiments, through X-ray tomography, have been conducted in order to identify the first order parameters, allowing to explain the observed structural evolution of the prism. Its 3D evolution have been registered through time, and we illustrate the dominant impact of; not only of the sedimentary loading (quantified ratio of Fragile/Ductile material deposited on the deformed units), but also the location of sediment deposition. This two first order "intra-prism" parameters interact with two "external" parameters; the shortening/dip-slip stress amount and orientation, and the basement configuration before the initiation of the compression. A tentative comparison with the Makran prism, developing in close tectonic conditions, will be done.

S10-6

"SOFT" OROGENIC COLLISION: WHAT DOES IT MEAN - THE CARPATHIANS EXAMPLE

Matenco Liviu¹, Krezsek Csaba², Merten Sandra¹,
Schmid Stefan³, Cloetingh Sier¹ y Andriessen Paul¹

¹VU University Amsterdam, Faculty of Earth and Life Sciences

²Chevron Norge AS, Oslo, Norway

³University of Basel, Institute for Geology and Paleontology, Switzerland

liviu.matenco@falw.vu.nl

The mechanisms controlling orogenic shortening and collision govern the evolution of coeval sedimentary infill and subsequent exhumation of foreland and back-arc basins. A first order observation of shortening is dating deformations along frontal sole thrusts. Hence continental collision represents the moment when out-of-sequence deformation is widespread, like lateral extrusion or back-ward vergent thrusting. The latter indicated that orogenic steady states are largely made up by exhumation in the orogenic core, which is recorded in natural examples by hinterland exhumation associated with backthrusts (i.e. retro-shears) such as the Insubric line in the Alps. The low topography Carpathians orogen is a typical case where retro-shears, although speculated, have never been confirmed by upper crustal studies and one

can wonder if these are collision pre-requisites. Due to reduced exhumation, these types of orogens still preserve post-tectonic covers, allowing biostratigraphy dating of nappe stacking events and discrimination of post-orogenic deformation. Sequence stratigraphy in the hinterland, kinematics of the thin-skinned foreland and thermochronological exhumation of the orogenic core are combined to derive the mechanics of this orogen with low topographic build-up.

The Carpathians example demonstrates that the lower plate is not always a "conveyer belt", i.e. transferring and incorporating material into the upper plate. Orogens dominated by convergence exhume the material entering the collision zone along retro-shears with values reaching few tens of kilometers. The model is valid in Carpathians-type of orogens dominated by subduction in those moments of gradual nappe accretion, until thicker continental parts of the lower plate arrive at the subduction zone. Subsequent deformation may couple the entire lower plate along higher angle reverse faults. These are retro-shears because particles are moving hinterland-wards, but structurally are foreland-vergent thrusts. Upper plate retro-shears as backthrusts are therefore not a pre-requisite of collision. Particle tracking in the upper part of the system will respect the general rules of exhumation in both scenarios. However, while retro-shear collision will generally nest zones of reset ages against the retro-deformation front, the foreland-coupling collision will distribute these ages across the orogen due to the gradual shift of the lower plate accretion. The latter is a deeper-seated mechanism and therefore its activation moments can be detected by shifted exhumation ages and larger wavelengths near the surface.

Author index

Aguirre Díaz Gerardo de Jesús	S06-4	37	Nomikou Paraskevi	S06-1	36
Alzaga Ruiz Humberto	S03-5	26	Obrebski Mathias	S09-2 POSTER	48
Amrouch Khalid	S08-5	45	Obrebski Mathias	S09-3 POSTER	48
Andréani Louis	S03-1	24	Olesen Odleiv	S05-6 POSTER	33
Andriessen Paul	S10-6	54	Ortuño Arzate Felipe	S01-2	16
Aragón Manuel	S02-1	20	Ortuño Arzate Salvador	S03-3	25
Aranda García Mario	S03-1	24	Osadetz Kirk	S04-2	28
Artemieva Irina	S10-2	52	Osadetz Kirk	S05-3 POSTER	32
Artemieva Irina	S08-2	44	Pacheco Martín	S02-1	20
Artemieva Irina	S09-1 POSTER	48	Pamplona Uriel	S02-2	20
Bartsch Erik	S03-2	24	Papanikolaou Dimitri	S06-1	36
Bauer K.	S01-3	16	Pasquaré Federico	S07-2	40
Beekman F.	S01-3	16	Pasquaré Federico	S06-1	36
Beekman Fred	S10-1	52	Paton Douglas	S05-2 POSTER	32
Benguigui Amran	S10-5	53	Pécskay Zoltán	S08-3	44
Bertrand R.	S04-3	28	Pécskay Zoltán	S06-2	36
Biegert Ed	S03-2	24	Peña-Alonso Tomás A.	S07-4	41
Bird Timothy	S04-2	28	Peña-Alonso Tomás A.	S07-5	41
Böhnel Harald	S07-4	41	Piñero Lajas Doris	S02-3	20
Caranto Geoffrey	S08-4	45	Planke Sverre	S10-3	52
Carrasco-Núñez Gerardo	S06-3	37	Rangin Claude	S03-1	24
Carreño Ana Luisa	S02-1	20	Rodríguez Sergio	S06-3	37
Castro Raúl	S09-2 POSTER	48	Román Ramos Juan Rogelio	S03-2	24
Chen Zhuoheng	S04-2	28	Romo Jones José Manuel	S02-2	20
Cloetingh S.A.P.L.	S01-3	16	Rosas Lara Carlos	S03-2	24
Cloetingh Sierd	S10-1	52	Roure François	S03-3	25
Cloetingh Sierd	S10-6	54	Roure Francois	S03-4	25
Cloetingh Sierd	S05-2 POSTER	32	Roure Francois	S03-5	26
Cruz Mercado Miguel Angel	S03-2	24	Roy S.	S04-3	28
Delgado-Argote Luis A.	S07-3	40	Rust Derek	S07-2	40
Delgado-Argote Luis A.	S07-4	41	Salomon Mora Luis Enrique	S03-2	24
Delgado-Argote Luis A.	S07-5	41	Sánchez Ferrer Fernando	S03-2	24
Deville Eric	S10-5	53	Sandrin Alessandro	S05-5 POSTER	33
Díaz-Castellón Rodolfo	S06-3	37	Sassi William	S01-2	16
Dobrzhinetskaya Larissa	S08-1	44	Scheck-Wenderoth M.	S01-3	16
Ellouz-Zimmermann Nadine	S10-5	53	Scheck-Wenderoth Magdalena	S05-2 POSTER	32
Escalona Alcázar Felipe de Jesús	S07-3	40	Schmid Stefan	S10-6	54
Eyal Yehuda	S05-3 POSTER	32	Seghedi Ioan	S08-3	44
Faleide Jan Inge	S10-3	52	Seghedi Ioan	S09-4 POSTER	49
Faleide Jan Inge	S05-6 POSTER	33	Seghedi Ioan	S06-2	36
Feinstein Shimon	S05-3 POSTER	32	Sheridan Michael	S06-3	37
Ferket Helga	S03-3	25	Siebert Lee	S06-3	37
Flotté Nicolas	S03-1	24	Stratford Wanda	S05-6 POSTER	33
García Juan	S02-1	20	Swennen Rudy	S03-3	25
González Escobar Mario	S02-1	20	Szakacs Alexandru	S08-3	44
González Escobar Mario	S05-1 POSTER	32	Szakacs Alexandru	S06-2	36
González Fernández Antonio	S02-3	20	Team PETROBAR	S10-3	52
González Mercado Esmeralda	S03-4	25	Tensi Julien	S10-4	53
Granjeon Didier	S03-5	26	Thybo Hans	S01-1	16
Green Harry	S08-1	44	Thybo Hans	S05-4 POSTER	33
Guilhaumou Nicole	S03-3	25	Thybo Hans	S05-5 POSTER	33
Helenes Javier	S02-1	20	Thybo Hans	S05-6 POSTER	33
Hernández Pérez J. Antonio	S05-1 POSTER	32	Tibaldi Alessandro	S07-2	40
Hirsch K.K.	S01-3	16	Tibaldi Alessandro	S06-1	36
Hirsch Katja	S05-2 POSTER	32	Tormey Daniel	S07-1	40
Hubbard Bernard	S06-3	37	Tryggvason Ari	S05-6 POSTER	33
Husson Laurent	S03-1	24	Valencia Víctor	S07-4	41
Kadosa Balogh	S08-3	44	Velasco Tapia Fernando	S07-3	40
Kiselev Sergey	S09-3 POSTER	48	Vezzoli Luigina	S07-2	40
Kluesner Jared	S02-3	20	Vinnik Lev	S09-3 POSTER	48
Krezsek Csaba	S10-6	54	Weber Bodo	S07-4	41
Lacombe Olivier	S10-4	53	Weber Bodo	S07-5	41
Lacombe Olivier	S08-5	45	Wirth Richard	S08-1	44
Lagmay Alfredo Mahar Francisco	S08-4	45	Wong Victor	S09-5 POSTER	49
Lane Larry	S04-2	28	Yang Jingsui	S08-1	44
Le Pichon Xavier	S03-1	24	van Wees J. D.	S01-3	16
Le Roy Charlotte	S03-1	24	van Wees Jan-Diederik	S05-2 POSTER	32
Lonsdale Peter	S02-3	20	van Wees Jan-Diederik	S10-1	52
López Martínez Margarita	S02-3	20			
Lyngsie Stig	S05-4 POSTER	33			
Malo M.	S04-3	28			
Martín Arturo	S02-1	20			
Martín Arturo	S05-1 POSTER	32			
Martínez Reyes Juventino	S03-1	24			
Matenco Liviu	S10-6	54			
Mathieu Yves	S04-1	28			
Merten Sandra	S10-6	54			
Molina-Garza Roberto	S07-4	41			
Montagner Jean-Paul	S09-3 POSTER	48			
Mooney Walter D.	S05-7 POSTER	34			
Mouthereau Frederic	S10-4	53			
Mouthereau Frédéric	S08-5	45			
Nebel Oliver	S07-3	40			
Nielsen Christoffer	S05-4 POSTER	33			
Nieto Obregón Jorge	S06-4	37			

FIELD TRIP LOG

GULF OF CALIFORNIA RIFT SYSTEM: LAGUNA SALDA-VALLES CHICO-SAN FELIPE, BAJA CALIFORNIA, MÉXICO

Francisco Suárez-Vidal
Departamento de Geología
División de Ciencias de la Tierra
CICESE

Oblique rifts, in which rift margins are oblique to the direction of continental separation, are reasonably common in modern record, e.g. the Red Sea and Gulf of Aden, the Tanganyika-Malawi-Rukwa rifts and the Gulf of California (McKenzie *et al.*, 1970; Rosendhal *et al.*, 1992; Stoke and Hodges, 1989; Manighetti *et al.*, 1998; Nagy and Stock, 2000; Persaud, P., 2003; Persaud, *et al.*, 2003). Although, how the oblique rift evolves is not well known. Oblique rifting remain poorly understand relative to those orthogonal rifts, where the rift margins are approximately perpendicular to the extension direction, and to strike-slip system (Axen and Fletcher, 1998).

The Gulf of California is perhaps the best modern example of oblique continental rifting where we can study the processes of such rifting as they lead to the interplate transfer of a continental fragment. This area presents unique opportunities for understanding key processes at transtensional plate margins, which is important for energy and mineral exploration, as well as for interpretation of tectonics ancient continental margins (Umhoefer and Dorsey, 1997). One of the main features along the length of the gulf is the fault system which connects active basins (incipient spreading centers) from south to north (Fig 1). Two main structural regions are defined. From the mouth of the gulf to the latitude of the Tiburon and Angel de La Guardia Islands several basins bathymetrically are well expressed, among them; the Pescaderos, Farallon, Carmen, Guaymas, San Pedro Martir and Salsipudes Basins. All of them are connected through a right lateral strike-slip fault (Fig. 2).

North of the islands the active basins and faults are buried by a thick pile of sediments from the Colorado River. The arrangement and evolution of these basins and fault system is less understood. They may be less developed than the basins to the south. Recently several studies reveal the geometry of the Delfin Inferior, Delfin Superior and Wagner basins (Persaud, 2003, Persaud, *et al.*, 2003; Gonzalez-Fernandez, *et al.* 2005; Aragon and Martin-Barajas 2007; Gonzalez-Escobar, *et al* in press). These basins are not well developed like those to the south, although the tectonic and structural relationship is similar, they are connected by an active right lateral strike-slip faults which are part of the Gulf of California-San Andrea fault system.

TECTONIC AND GEOLOGICAL SETTING

The Gulf of California is an oblique extensional rift system where oceanic to continental structural transition along the North America-Pacific plate boundary takes place (Fig. 2). Active continental structures related to the San Andreas Fault system are linked with similar structures in the Gulf of California, forming the San Andreas-Gulf of California fault system (Nagy and Stock, 2000; Persaud, *et al.*, 2003; González-Fernández, *et al.*, 2005). In the northern Gulf of California the transtensional system is defined by several incipient spreading centers. Details concerning where and how the structural transition occurs are poorly known, because the area is covered with a thick Quaternary sedimentary sequence that obscures older geological features. The presence of the incipient spreading centers and transform faults is commonly inferred. Nevertheless such presence is not supported by geophysical data (Nagy and Stock, 2000). Alternative orientations for those segments are in better agreement with bathymetric data.

In the northern gulf two incipient spreading centers, the Consag and Wagner basins (Fig. 2), plays an important role in the tectonic process that is taking place along the Gulf of California. These submerged, poorly understood structures in the northernmost gulf undoubtedly accommodate some plate motion deformation. These structures; however, are not as clear as the tectonic features in the central Gulf of California and at its mouth (Curry, *et al.*, 1982; Lonsdale, 1989), where geophysical evidence, such as magnetic anomalies mark the presence of the spreading center, the rate of movement along the plate boundary is established and the seismic data are help to delineate the active fault in the region.

According with Fenby and Gastil (1991) the Wagner basin is an elongate basin oriented N-S (Gonzalez-Escobar, *et al.*, in press) (Fig. 3) bounded in the northeast by the Cerro Prieto fault and in the southwest by several strike-slip faults that connect with the Consag basin. On the western side there is a dacitic outcrop known as the Roca Consag (Consag Rock) that may be associated to young volcanic activity in the region (less than one million years old). Although no recent volcanism has been documented within the area, there is some seismic activity (Frez and González, 1991; Castro, *et al.* 2007) and high heat flow values which suggesting that the basin and associated faults are active.

At present the structural definition of the Wagner basin is based on geophysical information such as the analysis of seismic activity in the area (Lomnitz, *et al.*, 1970; Thatcher and Brune, 1971), seismic refraction, seismic reflection,

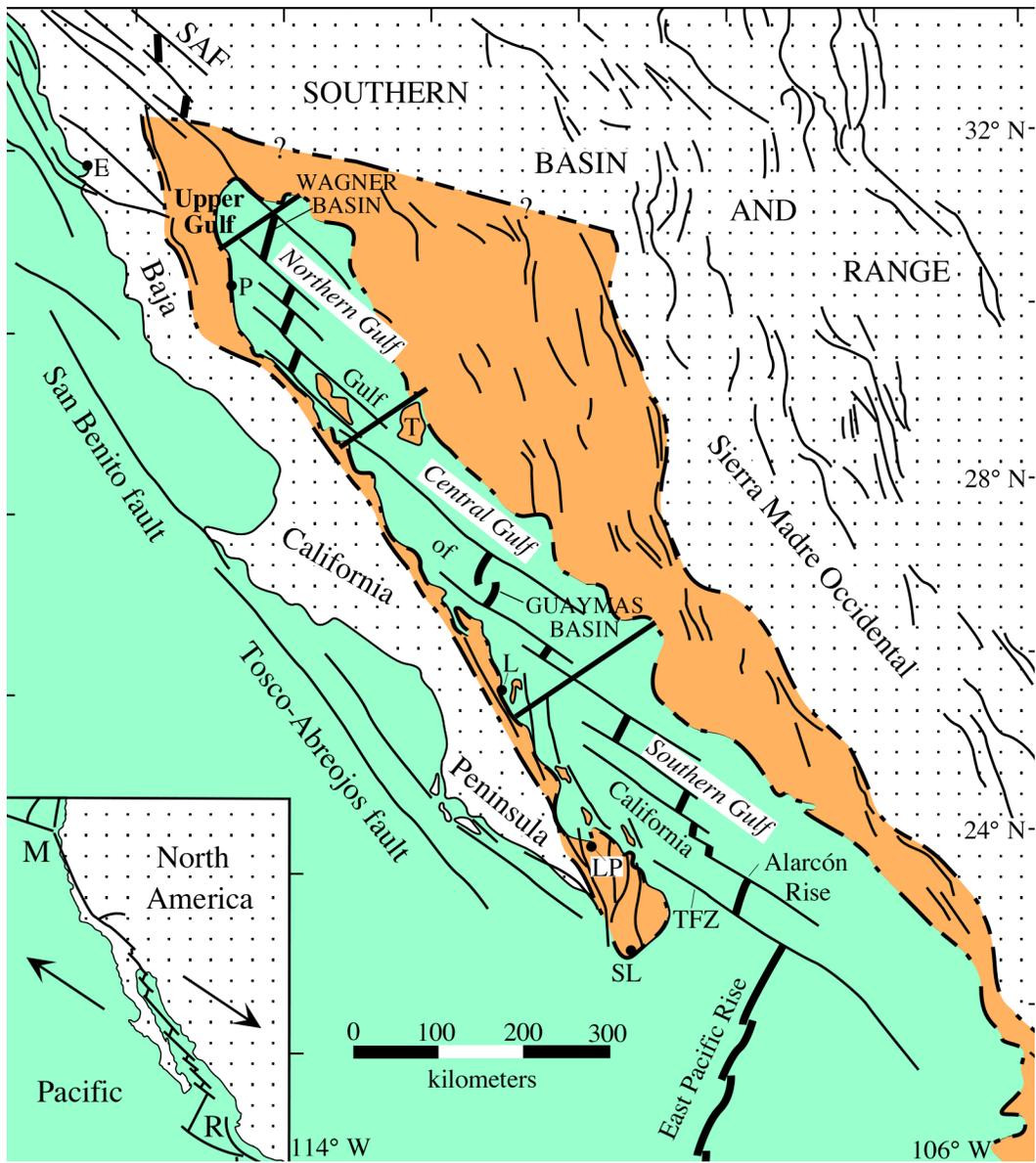


Figure 1. Tectonic map of The Gulf of California, regions, faults and basins.

gravity and magnetic (Phillips, 1962; Henyey and Bischoff, 1973; Pérez-Cruz, 1982; Couch, *et al.*, 1991; Persaud, *et al.*, 2003; Aragon-Arreola, 2006; Martin-Barajas, *et al.*, 2006; García-Abdeslem, 2006; Aragon-Arreola, and Martin-Barajas, 2007; Gonzalez-Escobar, *et al.*, in press). Nevertheless, the major structures are not well constrained and their trace are not well defined due to the high rate of sedimentation in the northern Gulf of California. Based on data from exploration wells drilled by Petroleos Mexicanos, (PEMEX) in the northern Gulf of California and on the analysis of large number of seismic reflection lines, the geometry and structural pattern of the Wagner basin is defined (Gonzalez-Escobar, *et al.*, in press). The importance of the Wagner basin within northern Gulf of California tectonic framework is very important, since is the link between the spreading centers in the gulf with those located to the north, in the Salton Sea structural province, such as the Cerro Prieto and the Brawley pull-apart basin.

STRUCTURAL FRAMEWORK

The Salton Trough province, located in southern California, USA, is a wide active basin trending in a NW-SE direction (Fig. 4). This province is the northern extension on land of the Gulf of California depression. In the structural and tectonic map of the Salton Trough made by Fuis and Kohler (1984), the Brawley and the Cerro Prieto oversteps appear as the tectonic connecting elements between the right-stepping dextral faults across the region. These releasing-oversteps are the locations of immature pull-apart basins known to be developing as part of the Pacific-North America plate boundary.

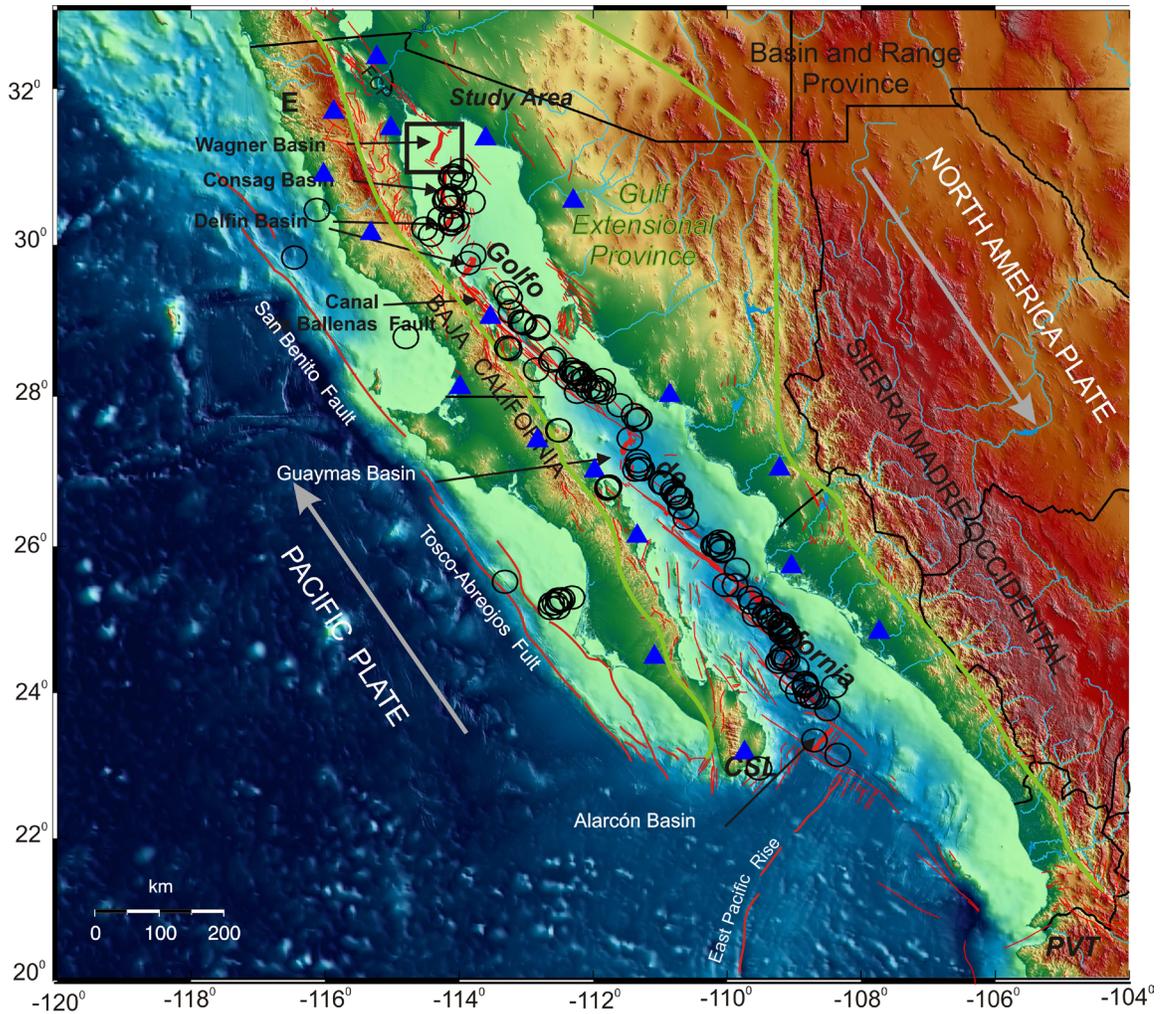


Figure 2.- Seismic activity associated to the principal active faults in the Gulf of California

The Salton Trough tectonic province represents the transition from an oblique rift boundary, along the Gulf of California, to a transform plate boundary, such as the San Andreas Fault system. Within this province exist a group of active transform faults, among them: the Cerro Prieto, Imperial, Brawley faults, and the southern extension of the San Andreas Fault, all of which constitute the Pacific-North America plate boundary at this latitude (Fig. 4).

These faults strike NW-SE and they give rise to an arrangement of right-stepping en-echelon faults that bound and connect sub-basins that constitute northern extension of the active oceanic spreading centers located in the Gulf of California (Fig 4). This system of stepped faults and sub-basins is similar to the observed in the Gulf of Aden (Manighetti *et al.*, 1998), the Central Gulf of California (Saunders *et al.*, 1982) and in the Salton Trough (Fuis and Kohler, 1984; Lonsdale, 1989), where several pull-apart sub-basins are in developing stage. Within the Salton Trough province, one of the developing pull-apart basins is the Cerro Prieto basin in the Mexicali, Baja California, Valley. This basin is in continuous structural evolution controlled by the dextral strike-slip Cerro Prieto and Imperial faults (Fig 4).

CERRO PRIETO PULL-APART BASIN

The Cerro Prieto fault zone extends in a northwest direction, from the northern Gulf of California (Wagner Basin) to the Cerro Prieto Volcano, and has been inferred to extend further north up to 20 km before the international border (Gastil *et al.*, 1975), whereas the Imperial fault forms a right-step with respect to the Cerro Prieto fault. Both faults are separated 13 km and extend into the Imperial Valley. The Imperial fault links the Cerro Prieto and Brawley pull-apart basins (Fig. 4), which are sedimentary basins formed within a zone of strike-slip deformation. This zone is characterized by active seismicity along parallel and oblique faults (Fig 5) with areas of infrequent large earthquakes in locked segments, and frequent small earthquakes along unlocked segments. This is the case of the Cerro Prieto basin filled with up to 6000 m of Tertiary and recent sediments (Pelayo *et al.*, 1991) that have experienced continuous deformation due to the high heat flow and the strike-slip movement imposed by the Cerro Prieto and Imperial faults.

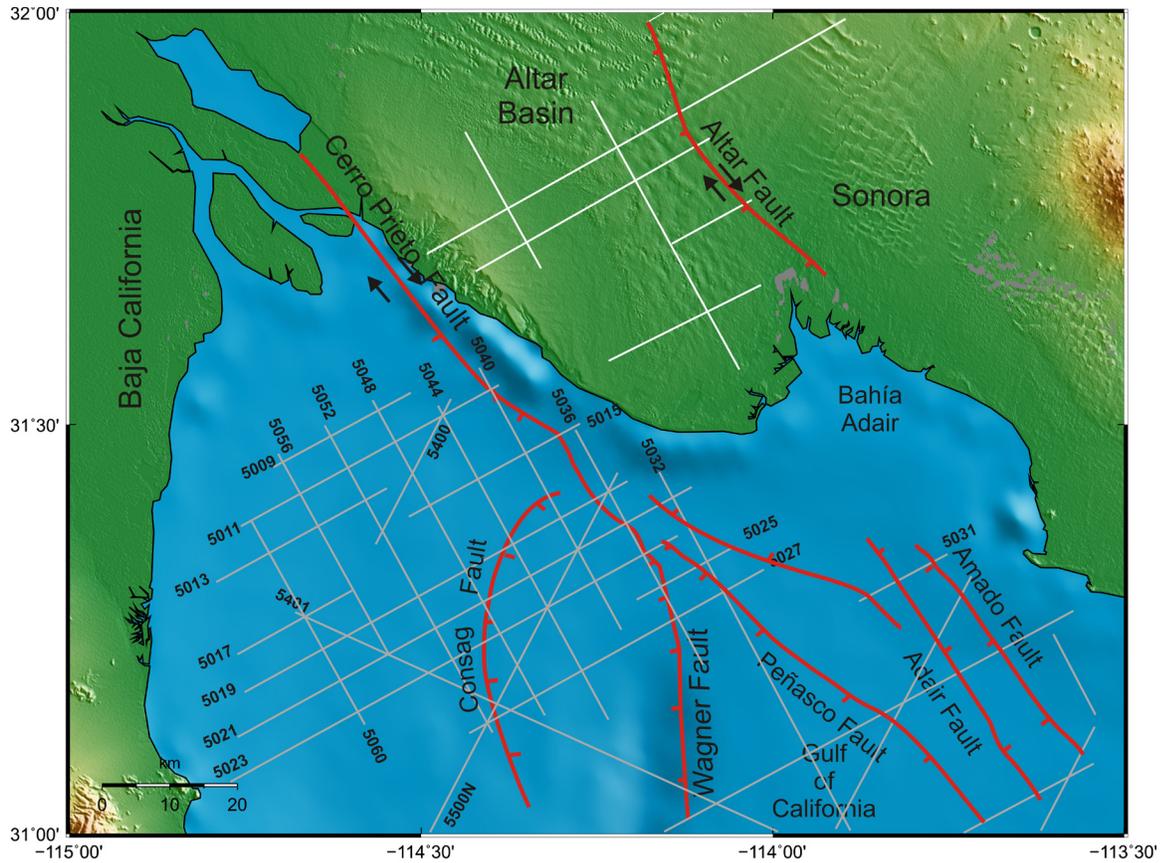


Figure 3.- Shape of the Wagner basin in northern Gulf of California based upon seismic reflection studies (after Gonzalez-Escobar *et al.*, in press)

According to Lachenbruch, *et al.* (1985) the thinning of the crust and the development of the Cerro Prieto basin was rapid, allowing the upwelling of magma from the asthenosphere creating new oceanic-type crust with a high heat flow. At the same time, subsidence took place at a rate proportional to the sedimentation that in the case of the Cerro Prieto basin was high due to the influx of the Colorado River that transported large volumes of sediments. In recent time, however, the amount of sediment transported by the Colorado River hydraulic regime has diminished due to damming of the river.

If the Lachenbruch *et al.* (1985) model applies to the Cerro Prieto basin, the crust in this area is being intruded by gabbroic magma, while subsidence is accompanied by rapid sedimentation that keeps the surface near the sea level, and isostatic balance is maintained (Lippmann *et al.*, 1997). Although this scenario has changed because the sedimentation stopped, the subsidence continues at high rate due to the inherited tectonic process associated to the slip on the two main active faults that bound the basin.

The tectonic regime associated with the Cerro Prieto basin has created an internal fault system characterized by several normal fault sets with different attitudes (Suárez-Vidal, *et al.*, 2008) (Fig. 6). This pattern of faulting was also observed in the early stage of development of other strike-slip basins (Nielsen and Sylvester, 1995). Lira-Herrera (2005) interpreted this structural pattern in Cerro Prieto as a half-graben structure with a depocenter close to the Imperial fault.

Sierra de Cucapa-El Mayor

West of Cerro Prieto basin is the Sierra de Cucapa and Sierra el Mayor these barren mountains rise abruptly from below sea level to as high as 1,100 m. The Sierra Cucapa consists of a series of tectonic slices of igneous, metamorphic and sedimentary rocks separated by major oblique dextral and normal fault zones. The oldest units in the range are Paleozoic, prebatholithic metamorphic rocks consisting mostly of well-banded, coarse-grained quartzfeldspathic gneiss and marbles. Lesser amounts of biotite-rich schist, amphibolites and quartzite, are also present. All these units are intruded during the Mesozoic by plutonic rocks of the Peninsular Range province (Fig 7).

The pre-Cenozoic igneous and metamorphic rocks have in turn partially overlain by Miocene volcanic units consisting of autobreccia flows and dikes. Pliocene and younger sedimentary units are exposed within and along the margins of the Sierra Cucapa and make the bulk of basin fills within Laguna. Deposition of these sediments into Laguna Salada has been dependent of marine incursion from the Gulf of California; the position of the Colorado River, and continued

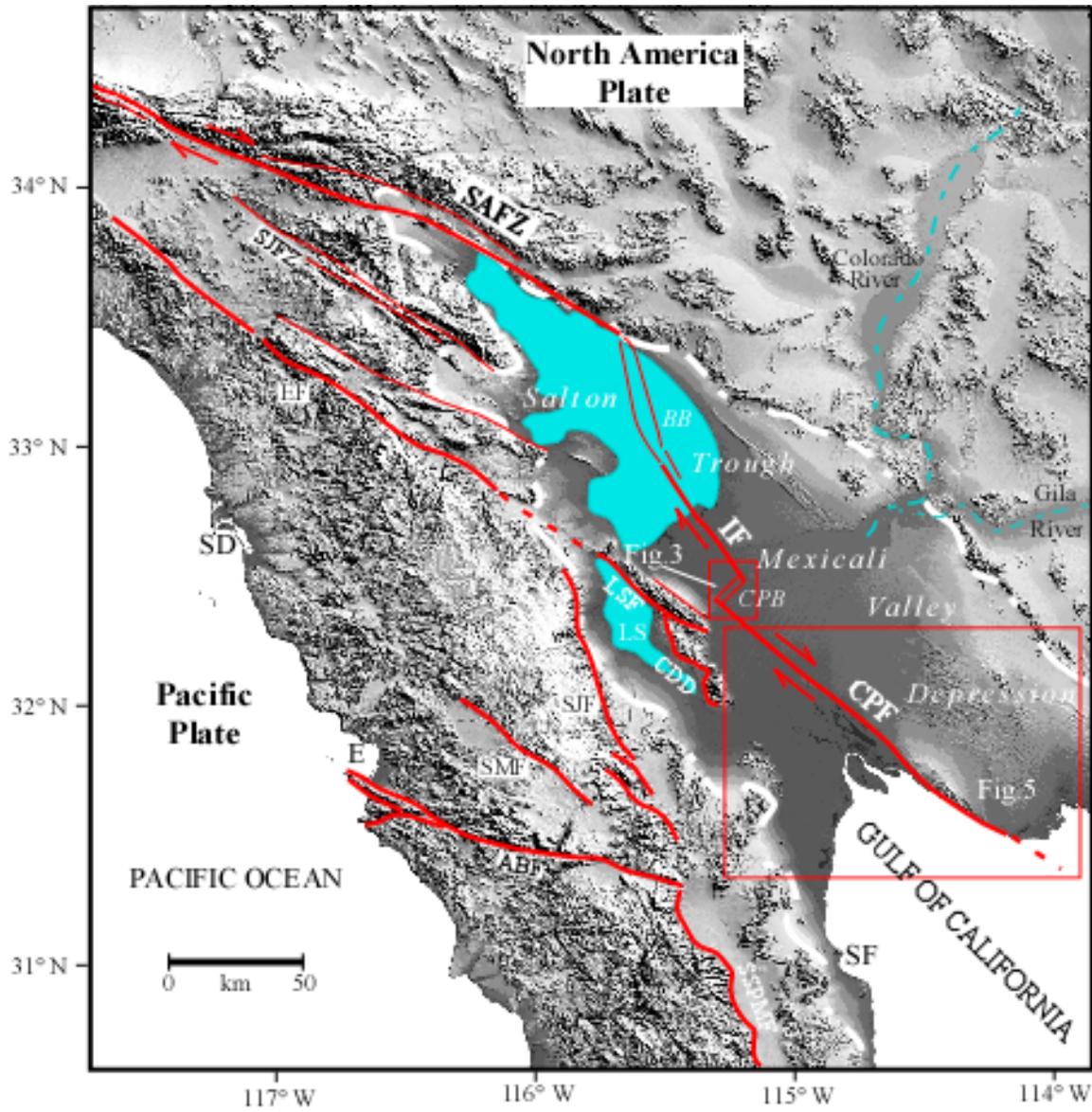


Figure 4.- Principal tectonic elements in Southern California-Northern Baja California, (after Suarez-Vidal, *et al.*, 2008)

localized variable uplift of the ranges that define the edges of the basin (Mueller and Rockwell, 1991; Martin-Barajas, *et al.*, 2001).

The lithologies in Sierra el Mayor consist of Cenozoic sedimentary cover rocks, Paleozoic metasedimentary and Mesozoic to Tertiary igneous basement rocks (Siem, 1992). The sedimentary cover rocks range in age from Miocene to present, with the majority of the section consisting of the marine Imperial Formation and the non-marine Palm Spring formation. These units are capped both conformably and unconformably by Quaternary conglomerates and alluvium. Exposed beneath the Imperial-basement detachment fault is a structurally intricate assemblage of Paleozoic metasedimentary rocks and they are intruded by plutonic rocks predominantly granodiorites composition and migmatitized by combination of both magmatic and metamorphic processes.

The granitic rocks are ubiquitous throughout the basement and account for approximately half of the exposed rock volume. They have intruded metasedimentary rocks in the form of dikes, sills, laccoliths, and irregular shaped rocks, resulting in intimate intermixing of the two rock types. Locally, the rocks are migmatitic and pervasive intermixing has occurred, (Siem, 1992).

Paleozoic metasediments are comprised of pelitic gneisses and schists, banded quartzofeldspathic gneisses, calcareous chert argillites, quartzites, and metacherts (Fig 7).

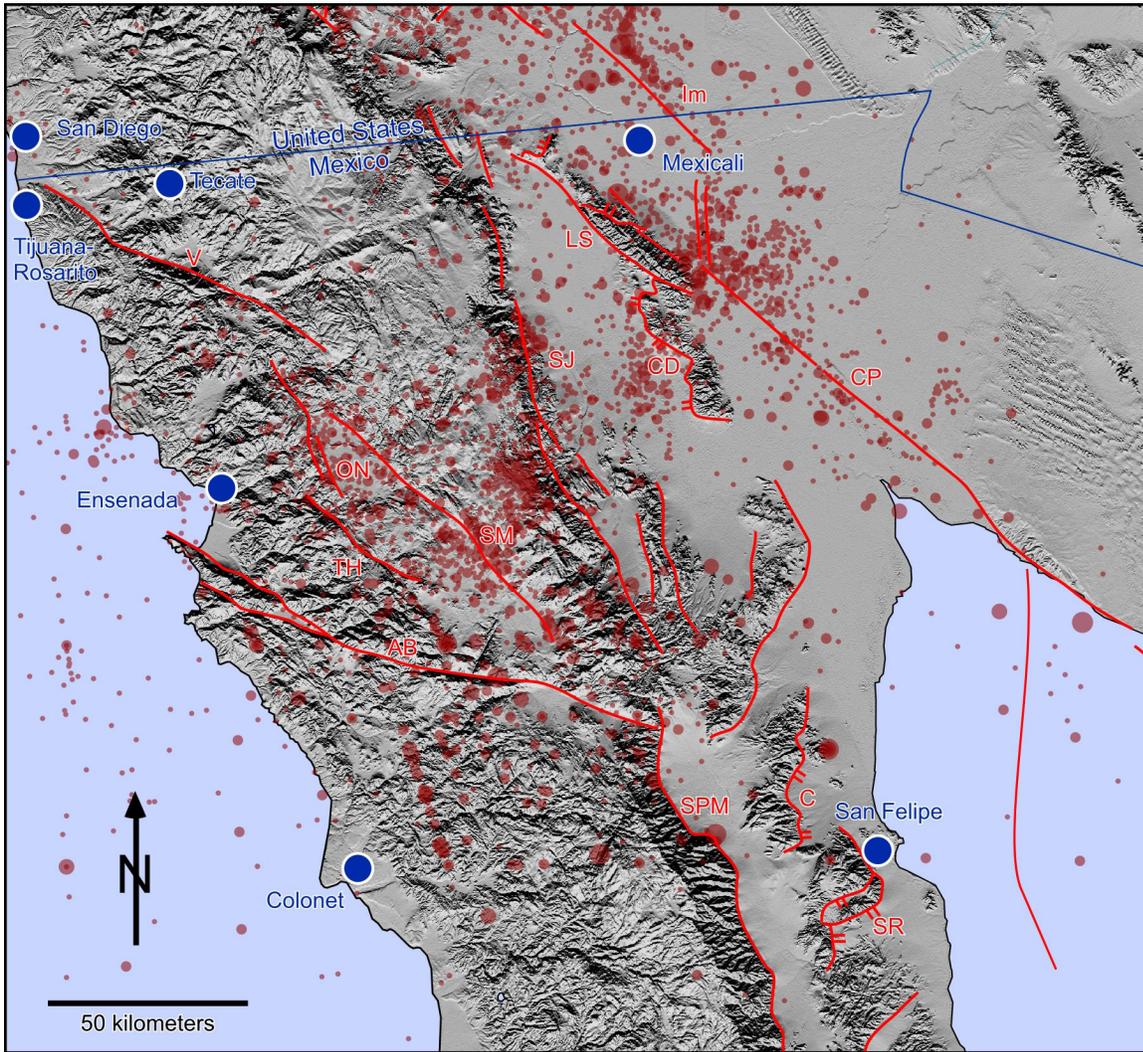


Figure 5.- Seismotectonic map of northern Baja California, with the main active faults including the Cerro Prieto basin in the Mexicali Valley.

Structurally, the northern range (Cucapa) is sliced by N 45° W right-lateral faults (Barnad, 1968a; Gastil, *et al.*, 1975; Mueller and Rockwell, 1991; Axen and Fletcher, 1998). Traced northwest, the faults commonly split in into several branches and take on a more northerly strike. The dextral Laguna Salada fault bounds the Cucapa range on its linear southwestern side against the Laguna Salada basin, where the active subsidence is taken place (Fig 8).

Other active faults in the area are: the Cañon Rojo normal fault, that apparently ruptured in widely felt 1892 earthquake (Strand, 1980; Mueller and Rockwell, 1991) and apparently this fault transfer much of the Laguna Salada fault movement to the western side of the Sierra el Mayor. The detachment faults in Sierra el Mayor may have had a similar relationship to the Laguna Salada fault, bounding the Plio-Pleistocene basin preserved in the northern part of the range.

The Borrego fault can be traced for 25 km north of the point where it splays form the Laguna Salada fault. The fault dips 50 to 60° toward the northeast where exposed, but much of the fault trace is covered by Holocene alluvium of the narrow basin along its trace (Axen and Fletcher, 1998).

The Pescaderos fault is exposed for 24 km along strike and is oriented N 40°W and dips 55° E (Barnard, 1968). The fault displays 3 to 3.5 km of right-lateral normal slip with a rake angle of 40 to 70° S, on the basis of the offset of two lithologic contacts with different orientation (Axen and Fletcher, 1998).

In contrast with the Sierra el Mayor the dominant structures are folds and low angle faults. The oldest structural elements recognized are west to northwest trending folds. The F1 folds verge both to the southwest and northeast. These generations of folds are typical cylindrical, non-parallel, asymmetric, tight to isoclinal folds (siem, 1992). The high angle normal faults (dips > 45°) form a conjugate system of listric and planar faults that are cutting the basement into a series of tilted fault blocks and horst and graben structures. These faults consistently strike 30° to 40° east and west, with the greatest concentration striking north and dipping to the west. The other fault system that controls much of the

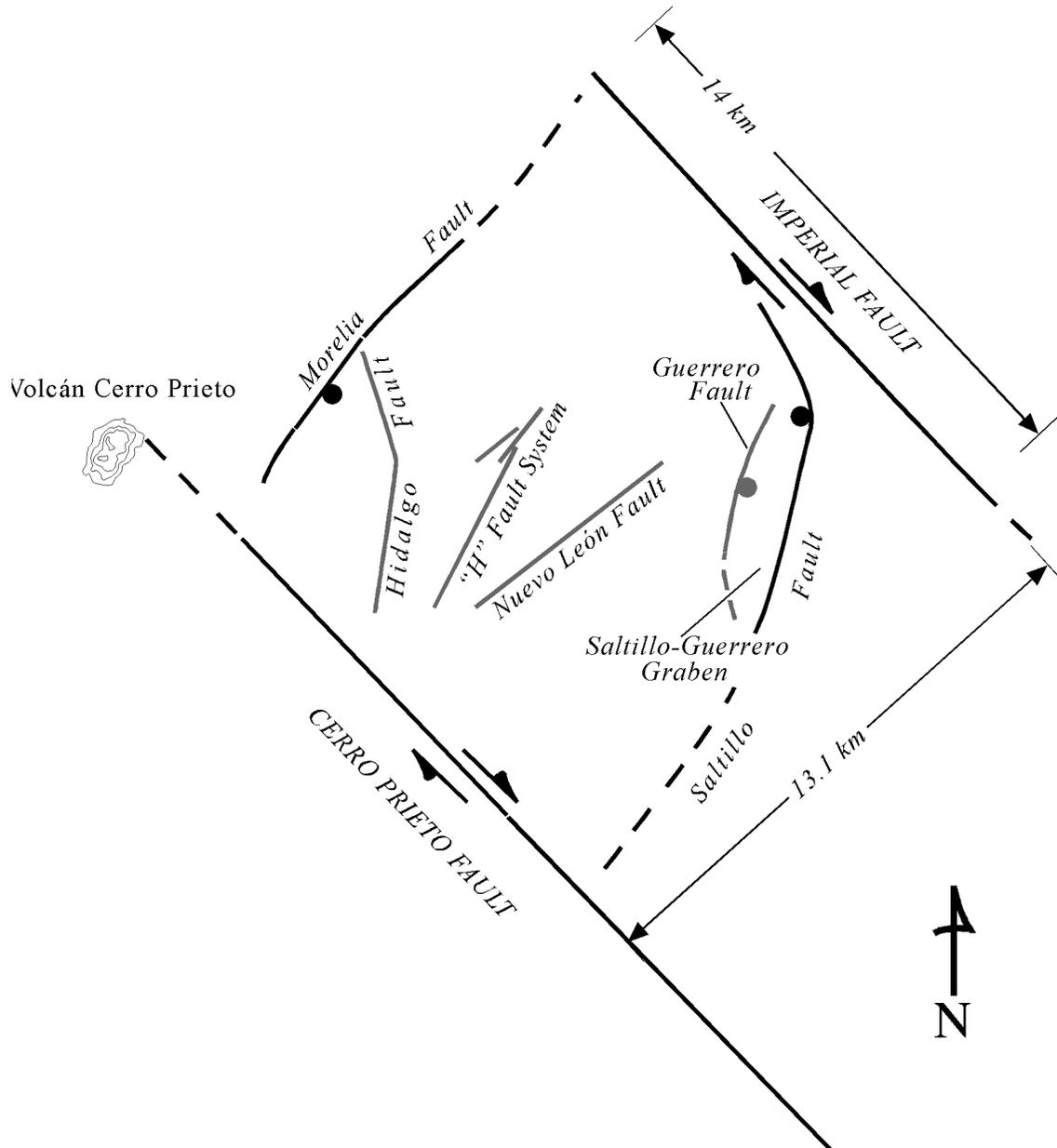


Figure 6.- Structural map of the Cerro Prieto pull-apart basin. The Cerro Prieto and Imperial faults are the main faults that controls the shape and grow of the basin.

deformation in the area, are the detachment fault known as the Cañada David and Monte Blanco faults (Siem, 1992; Axen and Fletcher, 1998).

LAGUNA SALDA BASIN

The Laguna Salada is and actively subsiding, sub-sea level basin that is bounded on the west by the Main Gulf Escarpment (Gastil, *et al.*, 1975), along the front of the Sierra de Juárez, which rises 1500 m above sea level. To the east is bound by the Sierra Cucupa - el Mayor and to the south by Sierra las Tinajas-Sierra Pintas. The most active subsidence is on the eastern side of the basin, adjacent to the northern Sierra el Mayor and Central Cucupa (Savage *et al.*, 1994) (Fig 7 and 8).

Basin development within the Laguna Salada appears to be related to the active oblique-dextral and normal fault zone exposed along the western margins of the Sierra Cucupa and Sierra El mayor. Kelm (1971) concluded that these faults define the very steep northeastern walls of the basin. The southwestern side of the basin appears to have had similar origin; however, the faults defining it have no surficial representation because of repeated late Holocene inundation, except for faults farther to the south which define the northern end of the Sierra Pintas (Muller and Rockwell, 1991; Gastil, 1968).

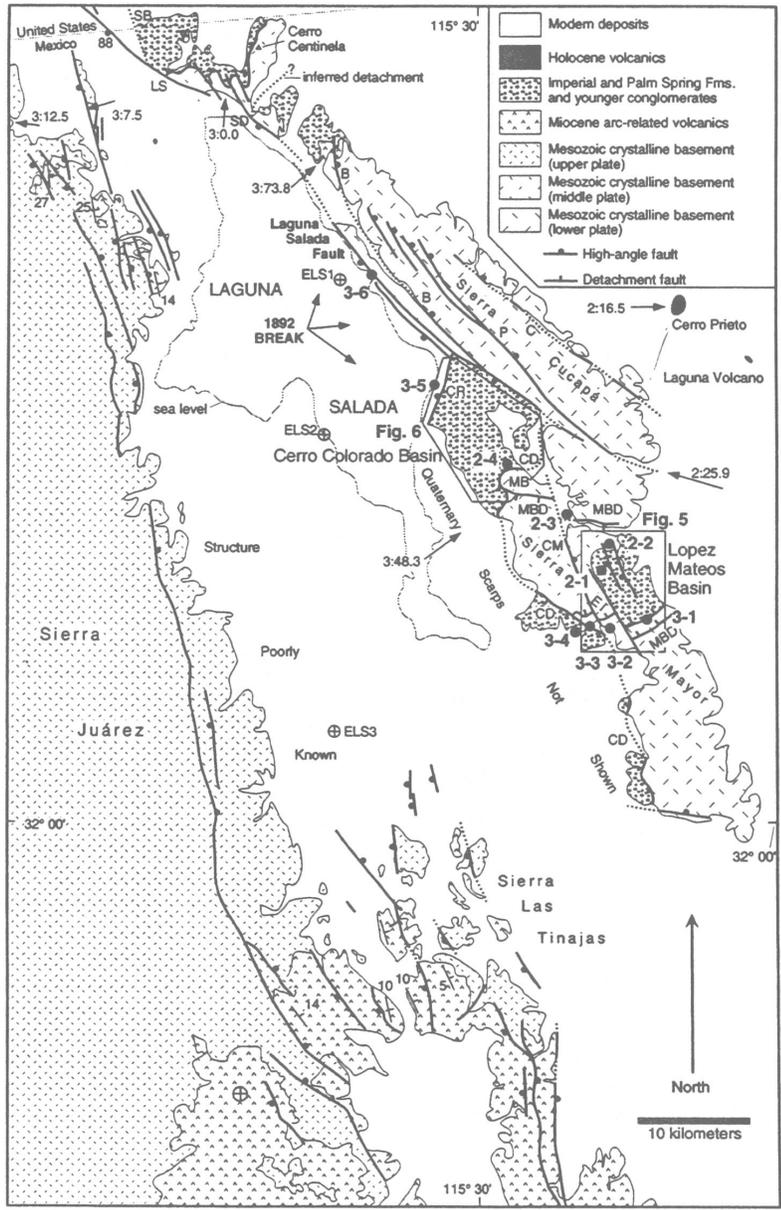


Figure 7. Simplified geologic map of the Laguna Salada region, showing locations of figures 5 and 6. Inset shows lower-hemisphere, equal-area stereonet plot of detachment-fault planes (n=19) and striae (dots, n=11); square is average striae. Geothermal exploration wells shown as circles with crosses. Abbreviations: B, Borrego; C, Cucapá fault; CD, Cañada David detachment; CM, central Mayor fault; CR, Cañón Rojo fault; LS, Laguna Salada fault; MB, Monte Blanco dome; MBD, Monte Blanco detachment; P, Pescadores fault; SB, Sunrise Buttes fault; SD, Sánchez Diaz fault. Modified from Axen and Fletcher (1998).

From the sedimentary point of view, the Laguna Salada basin provide insight into the evolution of marine and non-marine sedimentary basins that developed at the head of the Gulf of California rift system during Late Neogene time (Martin-Barajas, *et al.*, 2001). Sedimentary and tectonic events within the Laguna Salada and Imperial basins (to the north) register similar episodes of late Miocene to Pliocene detachment-related extension, which evolved to dominantly wrench tectonics along the Imperial and Cerro Prieto faults and intervening pull-apart basins (Axen and Fletcher, 1998). Both basin received their first marine incursions in late Miocene (Vazquez-Hernandez, *et al.*, 1996), and contain evidence of the progradation of the Colorado River delta. In Pleistocene time, the Laguna Salada basin became isolated from the Imperial Basin and from the Colorado River delta by tectonic activity on the Elsinore and Laguna Salada faults and the Sierra el Mayor detachment-fault. (Axen, *et al.*, 2000). The isolation produced lacustrine conditions alternating with episodic marine and fluvial flooding from the south. Continued subsidence and lower sedimentation rates maintained the basin floor below sea level.



Figure 8.- Aerial photos of the Sierra Cucapa and the trace of the Laguna Salada fault, (photos take by John Fletcher 2005

MAIN GULF ESCARPMENT (SIERRA JUÁREZ SEGMENT)

The main Gulf Escarpment extends from Mount San Jacinto in Southern California down the length of Baja California (Gastil, *et al.*, 1975). The escarpment has been produced by movement along a network of high angle faults. These faults can be seen north of the international border, as well as on the la Rumorosa, just south of the border and elsewhere along the western edge of Laguna Salada basin. Most of these fault strikes in NW direction and dip steeply to the east and to the west. W-dipping faults are abundant but faults with largest documented vertical separation dip east (Axen and Fletcher, 1998). Low angles faults are not common in the Sierra de Juárez but to sub-horizontal faults, one of which is surrounded by tens of meters of chloritic fault gouge and penetrative breccia, were observed in basement rock of northern Sierra Juárez (Axen and Fletcher 1998). Gently east-dipping, lower and middle Miocene sedimentary and volcanic strata are found in the escarpment of both northern and southern Sierra Juárez, where they are faulted by both east and west dipping faults (Mendoza-Borunda and Axen, 1995; Romero-Espejel, 1997). Farther west on top of the range, these sequence are subhorizontal so that they define a faulted east dipping monocline as the escarpment is traversed. This geometry has been attributed to reverse drag above the detachment system exposed on the Sierra el Mayor, which roots west under Sierra Juárez (Axen 1995; Axen and Fletcher, 1998), although a strike slip component has been documented on many of these faults and may account for their east dip as well (Mendoza-Borunda, *et al.*, 1995).

SIERRAS PINTAS, SAN FELIPE, SANTA ROSA, VALLE CHICO-SAN FELIPE AND MAIN GULF ESCARPMENT (SAN PEDRO MARTIR SEGMENT)

The structural province that includes Sierra Pintas, Sierra de San Felipe, Sierra de Santa Rosa, Valle Chico-San Felipe and the Main Gulf Escarpment in Sierra San Pedro Martir, extends from the Main Gulf Escarpment to the gulf and from Sierra Pintas in the north to Valle Chico on the south. It is characterized by intermountain basins and northeast trending faults.

The most prominent basin in the province is the Valle Chico-San Felipe graben (basin) that separates the Main Gulf Escarpment (Sierra San Pedro Martir) from the other ranges, San Felipe and Santa Rosa. From gravity and magnetic maps Sliker (1970) calculate the fill in the valley to be 2,400m thick. If this is the real depth of the basement, there have been 5, 300 m of uplift along the San Pedro Martir fault system which is formed by a series of concave normal fault that dip to the east. This group of faults bounds Valle San Pedro Mártir and Valle Chico. Besides the San Pedro Martir fault, two other regional lineaments can be seen on landsat scenes and skylab space images (Fig 9). The first, is oriented northwest, is formed by the Sierra de Juarez fault. The fault extends south into the Valle San Felipe (where is called the San Felipe fault), through the central part of the Valle San Felipe and Valle Chico to Arroyo Matomi. The second lineament, known as the El Chinero is 35-40 km east of the San Felipe fault, and has the same orientation. It extends northward 80 km from el Chinero to Sierra el Mayor and marks the boundary between Pliocene-Quaternary alluvial fans and the saline deposits associated with the Colorado River delta.

As a result of different studies along the San Felipe fault it has been concluded that this structural feature is characterized by a right lateral strike-slip movement and the main stress component is tensional. Together, the structural features (normal and strike-slip faults) give shape to a half graben downthrown to the east. Some of antithetic faults give shape to an asymmetrical dilation basin, filled with 2,400 m of Miocene-Pliocene sediments.

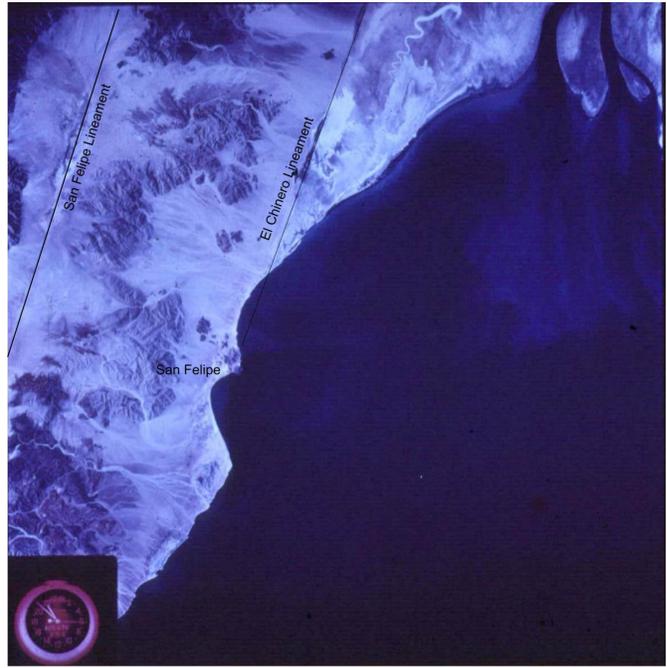


Figure 9.- Images of the Main Gulf Escarpment, (Sierra de San Pedro Martir), the San Felipe, El Chinero lineaments and the Valle San Felipe (San Felipe basin) (images from google and Sky Lab)

ESTRUCTURAL RELATIONSHIP OF ACTIVE FAULTS IN NORTHERN BAJA CALIFORNIA AND SOUTHERN CALIFORNIA

Southern California and northern Baja California form a common region affected by a number of regional-scale active faults, all constituting part of the San Andreas-Gulf of California fault system. The regional distribution of these fault are form east to west: Cerro Prieto-Imperial faults located in the Mexicali-Imperial Valley, and the Cucapa and Laguna Salada faults constitute the southern extension of the Elsinore fault. South of Laguna Salada there is two lineaments, El Chinero and San Felipe. The San Felipe lineaments extend southward, connecting with the extensional region near Puertecitos Baja California. West of the two lineaments, the San Pedro Martir fault and the Sierra Juarez fault constitute part of the Main Gulf Escarpment. In the peninsula ranges of Baja California, two main active fault systems are recognized: the Agua Blanca fault, which is oriented anomalously counterclockwise to the general trends of the southern San Andreas Fault system, and the San Miguel-Vallecitos faults, which extend from Sierra de Juárez escarpment toward the Tijuana-San Diego area. Both systems extend offshore and connect with active faults in the Continental Borderland.

All these faults are seismically active to different degree as a result of the interaction between the Pacific-North America plates in the Gulf of California region. Although in the northern Gulf the amount of displacement measured between plates is less than in the southern Gulf, the difference in movement can be spread along the strike-slip faults on the peninsula and those on the continental borderland. A structural relationship should exist between the Canal de Ballenas fault and the Puertecitos extensional region, which is the conduit where movement is induce to the onshore peninsula faults.

There in no doubt that the Imperial, Cerro Prieto, Laguna Salada, Cucapa faults play an important role in the neo-tectonic processes in northern Baja California. Through these structural features, the San Andreas Fault system connects with the Gulf of California fault system, which together forms the principal translation boundary between North America and Pacific plate. Much of the relative displacement between these two plates (perhaps half the motion) is taking place along these faults (Fig 10).

As the relative motion between the North America and Pacific plates is distributed over a broad system of subparallel faults, the relative movements along these various strands have change with time. It is entirely conceivable that throughgoing strands connecting the Los Angeles Basin with the Gulf of California is under development and that the faults which have been described here are an early part of this development. If this is true, every segment in the region, whether previously broken or not, could potentially become part of the tectonic process just as certainly as if it lay along of well-developed fault. This is valid not only for the Newport-Inglewood-Rose Canyon-Vallecitos-San Miguel zone, but

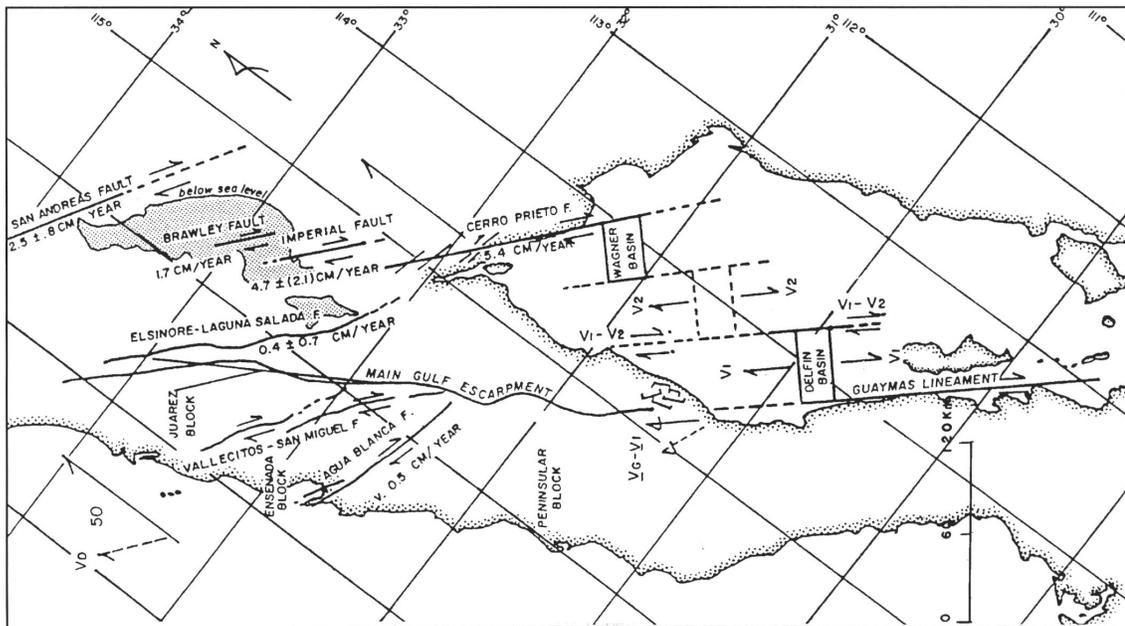


Figure 10.- Schematic map of the northern peninsula of Baja California, of southern California, and of the northern Gulf of California, illustrating the structural relationship between active faults in the area and their apparent slip rate. The total vector sum gives the 6.0 cm/yr equivalent to the rate of displacement of the North American plate relative to the Pacific plate at the mouth of the Gulf of California.

also for the faults on the eastern side of the peninsula between the Peninsular Ranges and the Gulf of California. Because at present we do not know the complete seismic history of these faults, the recurrence time for large earthquakes is unknown. However, the geological evidence is clear that all of the faults mentioned are active to some degree, and such activity is a result of the broader tectonic process that is taking place along the boundary between the North America and Pacific plates.

REFERENCES

- Aragón-Arreola, M., 2006, Structural evolution of basins in the Northern and Central Gulf of California, Implications for rift kinematics and strain accommodation, Unpubl. Ph.D. Thesis, Centro de Investigación Científica y de Educación Superior de Ensenada, B. C., 146 p.
- Aragón-Arreola, M., y Martín-Barajas, A., 2007, Westward migration of extension in the northern Gulf of California, México. *Geology*, v. 35, p. 571-574.
- Axen, G.J., 1995, Extensional segmentation of the main Gulf escarpment, México and United States, *Geology*, v. 23, p.515-518
- Axen, G.J., and Fletcher, J.M., 1998, Late Miocene-Pleistocene extensional faulting, Northern Gulf of California, México and Salton Trough, California. *International Geology Review*, v. 40, p. 217-244
- Axen, G.J., Grove, M., Stockli, D., Lovera, O.M., Rothstein, D.A., Fletcher, J.M., Farley, K., Abbott, P., 2000 Thermal evolution of Monte Blanco Dome-Late Neogene low-angle normal faulting during the Gulf of California rifting and late Eocene disruption of extraregional river system. *Tectonics*, v.10 (2), p.197-212
- Barnard, F.L., 1968, Structural geology of the Sierra de los Cucapas, northeastern Baja California, México, and Imperial County, California: Unpublished Ph. D. University of Colorado, Boulder, 157p.
- Castro, R. R., Méndez, O., Pérez-Vertti, A., Mendoza, A., y Insunza, L., 2007, Seismicity in the Gulf of California Region Recorded by the NARS-Baja Array: Preliminary Results, American Geophysical Union, Joint Assembly, Acapulco, México, 22-25th May 2007.
- Couch, R. W., Ness, G. E., Sánchez-Zamora, O., Calderón-Riveroll, G., Douphin, P., Plasman, V., Coperude, S., Huehn, B., y Gumma, W., 1991, Gravity anomalies and crustal structure of the Gulf and Peninsular provinces of the Californias in Dauphin, J.P. and Simoneit, B.T., eds., *The Gulf and Peninsular Provinces of the California* American Association of Petroleum Geologist, Memoir 47, p. 25-45.
- Curry, J. R., Moore, D. G., Kelts, K., y Einsele, G., 1982, Tectonics and geological history of the passive continental margin at the tip of Baja California, Initial reports of the Deep Sea Drilling Project, U.S. Government, Printing Office. Washington, D. C., v, 64 p. 1089-1116.
- Fenby, S. S y Gastil, R. G., 1991, Geologic-Tectonic map of the Gulf of California and Surrounding Areas. in Dauphin J. P. and Simoneit, B.T., eds., *The Gulf and Peninsular Provinces of the Californias*, American Association of Petroleum

- Geologist, Memoir 47, p. 79-83.
- Frez, J., y González, J. J., 1991, Crustal Structure and Seismotectonic of Northern Baja. *In* Dauphin, J. P. and Simoneit, B. R. T. eds. The Gulf and Peninsular Provinces of the Californias. American Association of Petroleum Geologists, Memoir 47, p. 261-283.
- Fuis, G.S., and Kohler, W.M., 1984, Crustal structure and tectonics of the Imperial Valley region: in Rigsby, C.A., ed., The imperial Basin: Tectonics sedimentation and thermal aspects: Los Angeles, CA., Pacific Section, Society of Economic Paleontologist and Mineralogist, p. 1-13
- García-Abdeslem, J., 2006, Evolución Tectonoestratigráfica de las Cuencas del Norte del Golfo de California, Volumen 2, Métodos Potenciales, Reporte técnico No. 80303843, PEMEX. 48 pp.
- González-Escobar, M., Cesar, Aguilar-Campos, Francisco Suárez-Vidal, and Arturo Marti-Barajas, Geometry of the Wagner basin, Upper Gula of California, based on seismic reflection; *Internacional Geology Review*, in press.
- González-Fernández, A., Dañoibeitia, J.J., Delgado-Argote, L.A., Michaud, F., Cordoba, D., and Bartolomé, R. 2005 Mode of extensión and rifting history of Upper Tiburon and Upper Delfin basins, Northern Gulf of California, *Geophysical Research*, v. 110 (B01313) p.1-17
- Gastil, R.G., 1968, Fault system in northern Baja California and their relation to the origin of the Gulf of California: in Dickinson, W.R. and Grantz, A., eds; *Proceedings of conference on geological problems of the San Andreas Fault system: Stanford University Publications in Geological Sciences*, v. 11, p. 283-286
- Gastil, R. G., Phillips, R. P., and Allison, E. C., 1975, Reconnaissance geology of the state of Baja California: Boulder Colorado, Geological Society of America, Memoir 140, 170 p.
- Heney, T. L. and Bischoff, J. L., 1973, Tectonic elements of the Northern part of the Gulf of California, *Bulletin of the Geological Society of America*, v. 84, p. 315-330.
- Kelm, D.L. 1972, A gravity and magnetic study of the Laguna Salada area, Baja California, México, Unpubl., thesis, San Diego State University, 103 p.
- Lachenbruch, A. H., Sass, J. H., and Galains, S. P., 1985, Heat flow in southernmost California and the origin of the Salton Trough, *Journal of Geophysical Research*, Vol. 90, (B8), p. 6709-6736.
- Lippmann, M. J., Truesdel, A. H., and Gutiérrez-Puente, H., 1997, What will a 6 km deep well at Cerro Prieto find?, *Proceedings: Twenty-first Workshop Geothermal Reservoir Engineering, Stanford University, January 27-29, 1997*, SGP-TR 155, p. 1-10.
- Lira-Herrera, H., 2005, Actualización del modelo geológico conceptual de yacimiento geotérmico de Cerro Prieto, B.C., *Geotermia*, Vol. 18 (1), p. 37-46.
- Lomnitz, C., Allen, C., Brune, J., y Thatcher, W., 1970. Sismicidad y tectónica de la región norte del Golfo de California, México, resultados preliminares, *Geofísica Internacional*, vol. 10, p. 37-48.
- Lonsdale, P., 1989. Geology and tectonic history of the Gulf of California. *in* Winterer, D. y Hussong, M., eds., *The Eastern Pacific Ocean and Hawaii, The Geology of North America*, Geological Society of America, Boulder, CO., p. 499-521.
- Manighetti, I., Tapponnier, P., Gillot, Y., Jacques, E., Courtillot, V., Armijo, R., Ruegg, J. C., and King, G., 1998, Propagation rifting along The Arabia-Somalia plate boundary: into afar, *Journal of Geophysical Research*, 103, p. 4947-4974.
- Martin-Barajas, A., S. Vazquez-Hernandez, A.L. Carreño, J. Helenes, F. Suarez-Vidal, J. Alvarez-Rosales, 2001, Late Neogene stratigraphy and tectonics control on facies evolution in the Laguna Salada basin, northern Baja California, México, *Sedimentary Geology*, v. 144, p. 5-35
- Martín-Barajas, A., Abdeslem-García, J., Helenes Escamilla, J., González-Escobar M., Aragón-Arreola, M., y M. Pacheco-Romero, M., 2006, Evolución Tectonoestratigráfica de las Cuencas del Norte del Golfo de California. Volumen 1 – Integración de resultados. Reporte técnico No. 80303843, PEMEX. 63 p.
- McKenzie, D.P., Davies, D., and Molnar, P., 1970. Plate tectonics of the Red Sea and east Africa, 1970, *Nature*, v. 226, p. 243-248
- Mendoza-Borunda, R., and Axen, G.J. 1995, Preliminary analysis of the Late Cenozoic structural history of the southern Sierra Juárez fault zone in the vicinity of the main Gulf Escarpment, *Third international Meeting of the geology of Baja California, Abstracts of the Peninsular Geology of Baja California Society; LA Paz Baja California Sur*, v. p.126-127
- Mendoza-Borunda, R., Axen, G.J., and Frias, V., 1995, Callamiento normal en la parte sur de la zona de falla Sierra Juárez, en la vecindad del Escarpe Principal del Golfo: Evidencias de cambios en la dirección de extensión a esa latitud (?), *GEOS*, v.15 (2), p. 69
- Muller, K.J., and Rockwell, T.K., 1991, Late Quaternary structural evolution of the western margin of the Sierra Cucapa, northern Baja California, in. Dauphin, J.P. and Simoneit, B.T., eds., *The Gulf and Peninsular Provinces of the Californias: Memoir 47, American Association of Petroleum Geologist*, p. 249-260
- Nagy, E. A., y Stock, J. M., 2000, Structural controls on the continent-ocean transition in the northern Gulf of California, *Journal of Geophysical Research*, 105 (B7), p. 16.251-16,269.
- Nilsen, T. H., and Sylvester, A. G., 1995, Strike-slip basin: in Busby, C. J., and Ingersoll, R. V., eds., *Tectonic and Sedimentary Basin, Blackwell Sciences*, p. 425-458.
- Pérez-Cruz, G., 1982, Algunos resultados de la Investigación geológico-geofísica en la porción noroccidental del Golfo de California, *Boletín de la Sociedad Mexicana de Geólogos Petroleros*, V. 6, p. 71-77.

- Persaud, P., 2003, Images of Early Continental Breakup in and around the Gulf of California and the Role of Basal Shear in Producing Wide Plate Boundaries. Unpubl. PhD. Thesis, California Institute of Technology. 144 p.
- Persaud, P., Stock, J. M., Steckler, M., Martin-Barajas, A., Diebold, J. B., Gonzalez-Fernandez, A., y Mountain, G., 2003, Active deformation and shallow structure of the Wagner, Consag and Delfin Basins, Northern Gulf of California, Mexico. *Journal of Geophysical Research*. 108 (7): 2355 p.
- Phillips, R. P., 1964. Seismic refraction studies in Gulf of California, in T.H. Van Andel T.H. and G.G. Shor, Eds. *Marine Geology of the Gulf of California*, American Association of Petroleum Geologists, Memoir 3, p. 90-121.
- Romero-Espejel, H.G.H., 1997, Estructura y petrología en el norte de Sierra Juárez, Baja California; M. Sc thesis. Centro de Investigación Científica y de Educación Superior de Ensenada, B.C., 155 p.
- Rosendahl, B.R., Kilembe, E., and Kaczmarick, K., 1992, Comparison of the Tangayika, Malawi, Rukwa and Turkana zones from analyses of seismic reflection data: *Tectonophysics*, v. 213, p. 235-256
- Saunders, A. D., Formari, D. J., and Morrison, M. A., 1982, The composition and emplacement of basaltic magmas produced during the development of continental-margin basins: The Gulf of California, Mexico, *Journal Geological Society of London*, Vol. 139 (3), p. 335-346.
- Savage, J.C., Lisowski, M., King, N.E., and Gross, W.K., 1994, Strain accumulation along the Laguna Salada fault, Baja California, México, *Journal of Geophysical Research*, v. 99, p.18109-18116
- Siem, M.E., 1992, The structural and petrology of Sierra El Mayor, northeastern Baja California, México, Unpubl., thesis, San Diego State University, 244 p.
- Slyker, R., 1970 Geologic and geophysical reconnaissance of the Valle de San Felipe region, Baja California, México; Unpubl., thesis San Diego State University, 97p.
- Stock, J.M., and Hodges, K.V., 1989, Pre-Pliocene extension around the Gulf of California and the transfer of Baja California to the Pacific plate, *Tectonics*, v. 8 p. 99-115
- Strand, L. 1980, Pre-1900 earthquakes of Baja California and San Diego County: M.S. thesis, San Diego State University, 320 p.
- Suárez-Vidal, F., Mendoza-Borunda, R., Nafarrete-Zamarripa, L.M., Ramirez, J., 2008, Shape and dimensions of the Cerro Prieto pull-apart basin, Mexicali, Baja California, México, Based on the regional seismic record and surface structures, *International Geology Review*, vol. 50, DOI:10.2747/0020-6814.50.4.1.
- Thatcher, W., y Brune, J. N., 1971, Seismic Study of an Oceanic Ridge Earthquake Swarm in the Gulf of California, *Geophysical Journal of Royal astronomical Society*, v. 22, p. 473-489.
- Umhoefer, P.J., and Dorsey, R.J., 1997, Translation of terranes: lessons from central Baja California México, *Geology*, v.25, p. 1007-1010
- Vázquez-Hernández, S., Carreño, A.L., and Martin-Barajas, A., 1996, Stratigraphy and paleoenvironments of the Mioocene-Pliocene Imperial Formation in the eastern Laguna Salada area: in Abbott, P.L., and Cooper, J.D., eds., *Field conference guide book and volume for the annual convention*, San Diego, California, May 1996: Bakersfield California, Pacific Section, American Association of Petroleum Geologist, v. 73, p373-380.

Recordamos a todos los miembros de la Unión Geofísica Mexicana, A.C.
que la cuota para el 2008 es de \$400.00 para investigadores
y \$300.00 para estudiantes.

página internet: www.ugm.org.mx

Favor de hacer llegar su cuota a:

Ivonne Pedrín Morales
División de Ciencias de la Tierra
CICESE
Km 107, Carret. Tijuana-Ensenada
Ensenada, 22860, B.C., México
Correo electrónico: ipedrin@cicese.mx

Con un cordial saludo

Luis A. Delgado Argote y Ramón Zúñiga Dávila
Editores

Costo anual de anuncios en GEOS

Instituciones:	Comerciales y Gubernamentales	Académicas
Página completa	\$4,000.00	\$2,000.00
Media página	\$2,000.00	\$1,000.00

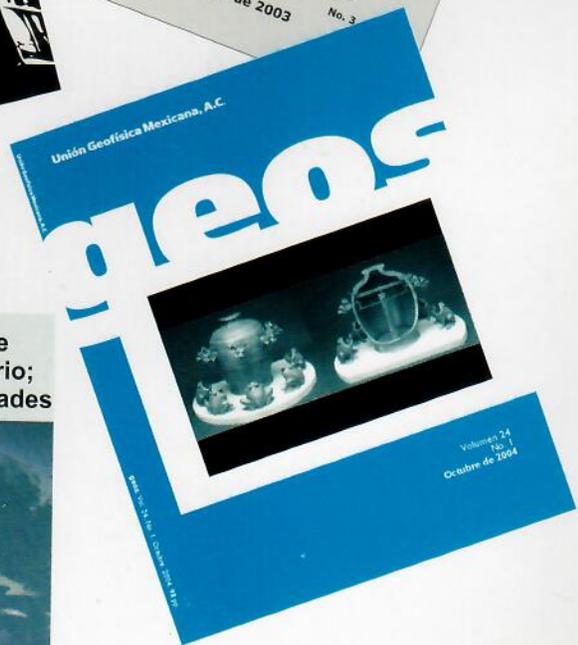
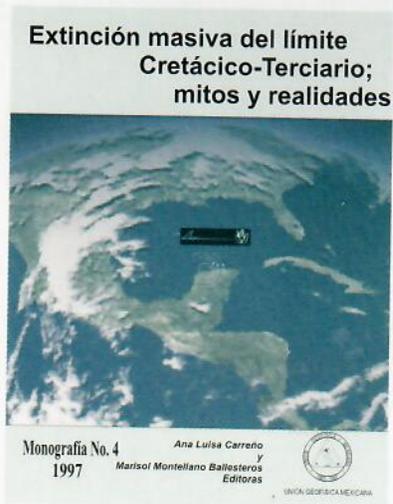
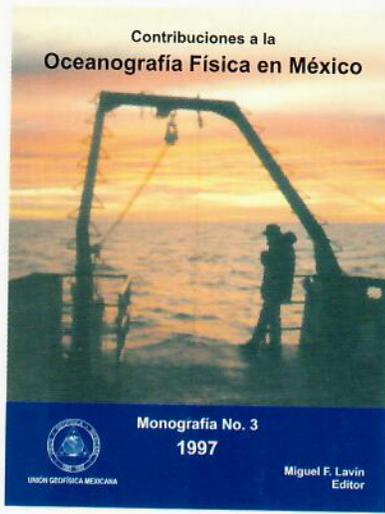
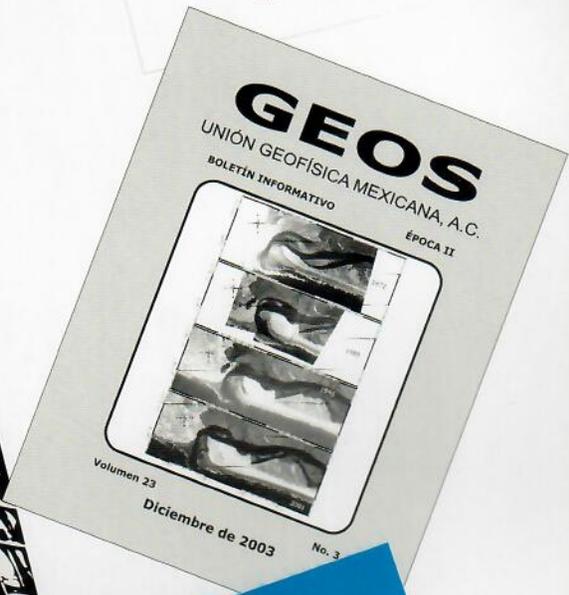
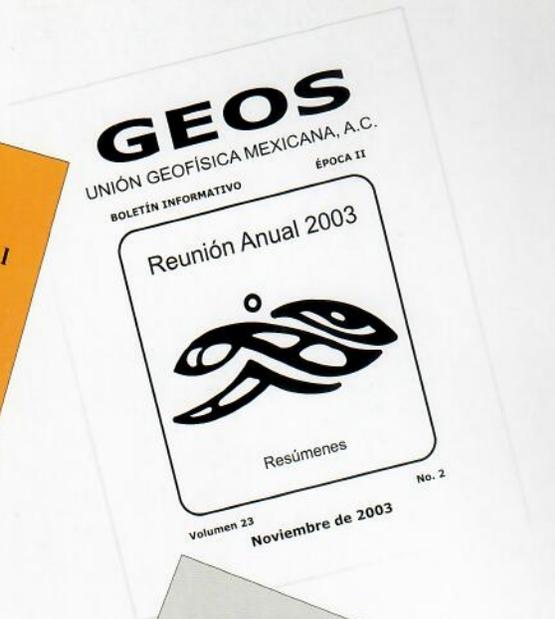
GEOS

Revista a la venta con:

Costo del ejemplar \$60.00

Ivonne Pedrín Morales
División de Ciencias de la Tierra
Tel: 01(646)174-5050
Ext: 26004
Correo electrónico: ipedrin@cicese.mx





Tus trabajos de investigación y divulgación tienen cabida en estos foros de la Unión Geofísica Mexicana, A.C.