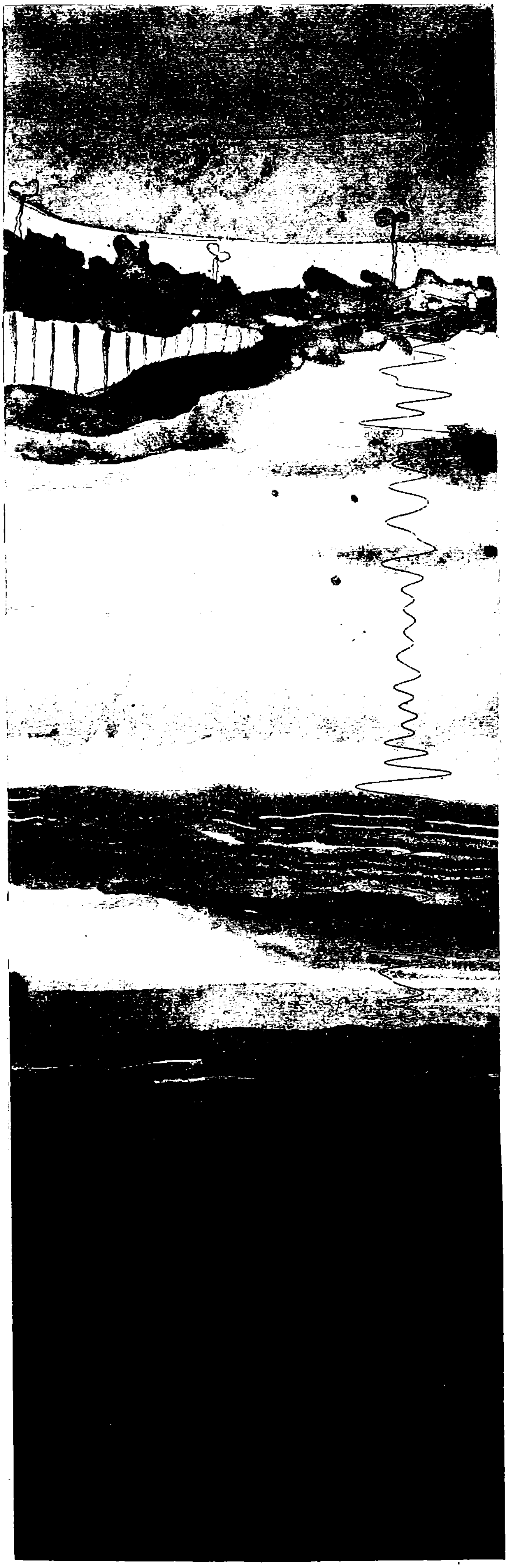
Bruce Goleby

8th International Symposium on

DEEP SEISMIC PROFILING OF THE CONTINENTS AND THEIR MARGINS

20-25 September, 1998
Platja d'Aro Conference Centre
Barcelona, Spain



8th international symposium on

deep seismic profiling of the continents and their margins

program
and
abstracts

20-25 september, 1998
platja d'aro conference center
barcelona, spain

SPONSORS

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8th International Symposium
on
Deep Seismic Profiling of the Continents
and their Margins

General Information

Welcome

The Organizing Committee of the 8th International Symposium on Deep Seismic Profiling of the Continents, on behalf of the Consejo Superior de Investigaciones Cientificas (CSIC) and the University of Barcelona, welcomes you to Platja d'Aro Conference Center. We thank all participants for attending the meeting, and we wish you to enjoy the conference and your stay in Spain.

Organizing Committee

Chairpersons: Josep Gallart, Ramón Carbonell, Montserrat Torné
Dpt. of Geophysics, Institute of Earth Sciences, CSIC
Solé i Sabarís s/n, E-08028 Barcelona (Spain)
Phone: 34-93-4900552 Fax: 34-93-4110012

Members: E. Banda, J. Dañobeitia, A. Pérez-Estaún (CSIC)
P. Santanach, J.A. Muñoz, J. Pous (Universitat de Barcelona)

additional thanks to
L. Clavera, E. Serra and M.J. Prieto for artwork, layout and their patience
And all the Session Chairs & Open-Discussion leaders.

LOGISTICS

Meals

All meals will be served at the restaurant of the PlatjaPark Hotel, except Wednesday's Dinner that will be served at a Barcelona's restaurant.

Meal hours are:	Breakfast:	07:30-08:30
	Lunch:	13:15-14:30
	Dinner:	20:15-21:30

**You will need to present your meal ticket (see in your Registration packet) for every meal.*

Refreshment breaks

Coffee, tea and refreshments will be served at the Conference Center during coffee-breaks. One free soft drink will be served during the Poster Sessions. Tickets will be required. An open cash bar will be also available during the poster sessions.

Daily announcements

Program changes and any other announcements will be posted in the hall of the PlatjaPark Hotel and at the Conference Center.

Conference Office

The Conference Office is in front of the Conference Registration desk (Hotel main hall). It will be staffed by members of the Organizing Committee, normally from 14:00-15:00 and from 18:00-20:00. Internet access will be available from 09:00 to 20:00

Social and tourist activities

Information on the different tourist possibilities as well as on field trip guides of geological tours nearby Platja d'Aro will be provided by Maria Jose Prieto. A guide to the Pyrenees is also available. People interested in the Pyrenees should contact J.A. Muñoz for further information.

On Sunday evening (21:30) there will be an Icebreaker party at the Platja Park Hotel.

On Wednesday afternoon (after lunch) there will be an excursion to visit Barcelona city. This excursion includes a tourist trip around the city and dinner.

On Thursday evening there will be an special banquet and spectacle at the PlatjaPark Hotel.

Hotel Facilities

Parking, swimming pool, fitness, sauna and hydromassage are free of charge.

At the end of the conference

Return to Barcelona Airport, Friday 25th September

There will be Conference-organized transport to Barcelona Airport on Friday 25th September. Details on departure time will be announced during the conference.

Scientific presentations

Oral Presentations

All talks are in Platja d'Aro Conference Center (two min. walking from PlatjaPark Hotel). The time allotted to presentations (20 min. except invited talks) is intended to be used by the speaker, followed by short questions. All general questions and main discussions should be deferred to the Discussion period scheduled at the end of the session.

Audio-visual equipment

The Conference Center is equipped with two 35 mm slide projectors, two overhead projectors, and two screens. PC slide shows are also available.

Speaker ready room

Slide carousels are available in the Conference Center. A room in the Conference Center will also be allocated for training and pre-projection of presentation. Carousels may be pick up between 08:00-08:30 (morning speakers) and between 14:30-15:00 (afternoon speakers). Please return the empty carousels to the projectionist.

Poster Displays

All posters are allocated one side of a single 1.60 m width x 1.20 m height board, except those that had requested bigger boards. Posters will be displayed in the Conference Center.

All posters presenters should check the list to determine their number, and should use this number to locate the corresponding poster board. Posters should be put up on Sunday 20th September and must be taken down before 12:00 noon on Friday 25th. During poster presentations a cash bar will be open.

Coffee breaks

Coffee will be served outside the Conference Center if weather allows, otherwise it will be served inside the Conference Center.

Special announcements

Changes to the program and any announcements will be posted in the Conference Center and in the Reception Hall of the Hotel.

Participants wishing to display any notice may do so on poster boards and tables allocated for this purpose at the entrance of the Conference Center. A table will be also available in the Reception Hall of the hotel.

Ad hoc meetings and presentations

Following previous Symposia as in Asilomar, (1996), it is also our aim to stimulate debate on key points that can have important influence in our future research. Therefore, three special interest group discussions have been planned.

These meetings are scheduled on Monday and Tuesday evenings and will be held at a special lounge (about 70 seats) at PlatjaPark Hotel.

Monday 21, 22:00-23:00: *A Global Committee On Lithospheric Transects (COLT)*

Tuesday 22, 21:30-22:15: *New Technologies, New Applications, New Interpretations, New experiment designs*

Tuesday 22, 22:15-23:30 *Future activities and format of the CCSS and related Workshops.*

Break-out rooms

In addition to the Open Meetings' lounge, another lounge will be available for any conferee to book, for any sub-group to meet. That room seat about twelve people, and an overhead projector will also be available. Bookings should be made through the

Conference Office. If weather allows we recommend to meet at the swimming pool terrace flavouring a Spanish wine.

Proceedings Volume

The Organizing Committee has made preliminary arrangements with the publishers of Elsevier journal *Tectonophysics* for a Special Symposium Proceedings issue. This issue will be similar to those already published from previous Symposiums. In order to ensure the widest dissemination of the results presented in this Symposium we strongly encourage the participants to publish their presentations.

All those planning to submit a paper to the Proceedings Volume will be asked to indicate the probable authorship and title during the meeting.

Because the time to publication is controlled mainly by the speed on initial submission and because we wish to publish the volume one year after the meeting, we require the papers be submitted no later than **December 15th**. Three copies of the manuscript with all illustrations should be submitted to:

J. Gallart
Institute of Earth Sciences (J. Almera), CSIC
Sole i Sabaris s/n
08028-Barcelona (Spain)

All manuscripts will undergo rigorous revision, following the standard *Tectonophysics* procedure.

Next and Future Meetings

The 9th International Symposium on Deep Seismic Profiling will be held in Norway Organizers: Hans Thybo and Eystein Husebye *(see announcement next page).*

Scientists or Organisations wishing to host future Deep Seismic Meetings are encouraged to communicate their interest to the Organizing Committee before the end of the 8th International Symposium

9th International Symposium on

DEEP SEISMIC PROFILING OF THE CONTINENTS AND THEIR MARGINS

18-24 June 2000

will be held at the
Brakanes Hotel Conference Centre, Ulvik, Norway (www.brakanes-hotel.no)

The conference centre has all modern facilities, large auditorium, several smaller meeting rooms etc. International airports are located at Bergen (150 km) and Oslo (360 km).

The venue is at the shores of the Hardanger Fjord, in the heart of a beautiful tourist resort, situated only short drives from two of Norway's main glaciers and the famous Vöringfoss waterfall. The timing will allow a traditional Nordic bonfire on the eve of 23 June.

In view of the highly developed oil and gas industry in Norway, we would like to widen the scope of the symposium to include also new techniques developed by this industry. Presentations on the following themes are in particular encouraged:

New Frontiers
* High resolution imaging
* S-wave profiling & mapping
* Geophysical concepts of Geology
* Moho dynamics and imaging
* The 3D challenge

Uplift and Geomorphical modeling
* Uplift - glacial rebound
* Geomorphical modeling
* Case stories

Intracrustal deformations & dynamics
* Crustal stratification
* Tectonic fabric preservation
* Geological map - geophysical model
* Upper crust vs lower crust, erosion

Continental margins
* Passive margins
* Active margins

Oil Industry techniques
* 3D surveys
* Reservoir modelling
* Reservoir monitoring
* Shear-wave prospecting
* 4D profiling

Surveying Fennoscandia and adjacent seas
* Baltic, North, Norwegian & Greenland seas.
* Margins in the N. Atlantic
* Collision and amalgamation structures

The upper mantle
* Very deep normal incidence reflections
* Dipping mantle reflections, nature and origin
* Importance of velocity and structure
* The role of the mantle in active tectonics

Intracontinental tectonics
* Rifts, basins and extensional provinces
* Palaeo-collision structures

Looking forward to welcoming you to the first deep seismics symposium in the next millenium,

Eystein Husebye
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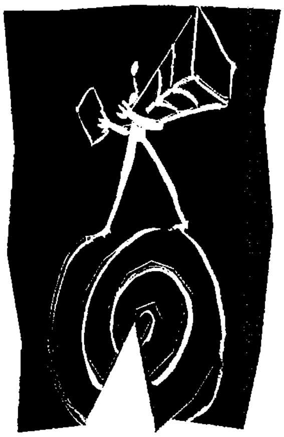

8th International Symposium on

Deep Seismic Profiling of the Continents and their Margins

20-25 September, 1998
Platja d'Aro Conference Center
Spain

Program

Oral Presentations Summary

Monday, 21 September	Tuesday, 22 September	Wednsday, 23 September	Thursday, 24 September	Friday, 25 September
SESSION T1: Active/Passive Margins	**SESSION T1: Active/Passive Margins**	**SESSION T4: Intra-continental collision**	**SESSION T5: Transects and syntheses: seismic signatures of Precambrian shields**	**SESSION T7: Seismic techniques: new developments**
8:30 WELCOME	8:30 von Huene, Roland	8:30 Cook, Frederick (Invited)	8:30 Oncken, Onno (Invited)	8:30 Hobbs, Richard W. (Invited)
8:50 Hinz, Karl (Invited)	8:50 Ito, Tanio	9:00 Drummond, Barry	9:00 Mooney, Walter D.	9:00 Morgan, Joanna
9:20 Sibuet, Jean Claude	9:10 Sato, Hiroshi	9:20 Morozov, Igor	9:20 Truffert, Catherine	9:20 Bean, Christopher
9:40 Sawyer, Dale	9:30 Hirata, Naoshi	9:40 Ross, Gerald M.	9:40 Pavlenkova, Nina I.	9:40 Barton, Penny J.
10:00 Laigle, Mireille	9:50 DISCUSSION	10:00 Eaton, David	10:00 Goleby, Bruce R.	10:00 DISCUSSION
10:20 Vidal, Neus	**SESSION T2: Integrated multidisciplinary studies**	10:20 DISCUSSION	10:20 DISCUSSION	10:10 COFFEE
10:40 DISCUSSION	10:00 Smithson, Scott (Invited)	10:30 COFFEE	10:30 COFFEE	**SESSION T8: Rifts, basins and**
10:50 COFFEE	10:30 COFFEE	11:00 Snyder, David B.	11:00 Brown, Larry D.	**extensional provinces**
11:10 Dañobeitia, Juan José	11:00 Hirn, Alfred (Invited)	11:20 Warner, Michael	11:20 Diaconescu, Camelia C.	10:40 Sawyer, Dale (Invited)
11:30 Scholl, David	11:30 Tryggvason, Ari	11:40 Teixell, Antonio	11:40 Echtler, Helmut	11:10 Magnani, M. Beatrice
11:50 Ranero, César R.	11:50 West, Gordon F.	12:00 Pous, Jaume	12:00 Carbonell, Ramon	11:30 Grad, Marek
12:10 Oncken, Onno	12:10 Meltzer, Anne	12:20 Ross, Andrew	12:20 Makovsky, Yizhaq	11:50 Egorkin, Anatoly
12:30 Reichert, Christian	12:30 Stern, Tim	12:40 Balling, Niels	12:40 DISCUSSION	12:10 Drummond, Barry
12:50 DISCUSSION	12:50 DISCUSSION	13:00 DISCUSSION	13:15 LUNCH	12:30 DISCUSSION & CLOSING
13:15 LUNCH	13:15 LUNCH	13:15 LUNCH		REMARKS
	SESSION T3: Imaging 2D and 3D heterogeneities and anisotropy	**14:30 VISIT TO BARCELONA (DINNER INCLUDED)**		**14:00 to 14:30 DEPARTURE TO BARCELONA AIRPORT**
15:00 Collins, Clive D.N.	15:00 Levander, Alan R. (Invited)		15:00 Clowes, Ronald	
15:20 Lorenzo, Juan Manuel	15:30 Hurich, Charles A.		15:20 Hajnal, Zoltan	
15:40 Liu, Char-Shine	15:50 Douma, H.		15:40 White, Donald	
16:00 COFFEE	16:10 COFFEE		16:00 COFFEE	
16:30 Della Vedova, Bruno	16:40 Thybo, Hans		**SESSION T6: Seismic reflection application**	
16:50 Maldonado, Andrès	17:00 Hobbs, Richard W.		**to natural resources and environment**	
17:10 Kodaira, Shuichi	17:20 Hansen, Thomas Mejer		16:30 Green, Alan G. (Invited)	
17:30 Ikawa, Takeshi	17:40 Nedimovic, Mladen		17:00 McBride, John H.	
17:50 DISCUSSION	18:00 DISCUSSION		17:20 Milkereit, Bernd	
18:15 POSTER SESSION	20:15 DINNER		17:40 DISCUSSION	
20:15 DINNER	21:30 OPEN SESSION 2		18:15 POSTER SESSION	
22:00 OPEN SESSION 1	22:15 OPEN SESSION 3		20:30 BANQUET	

SCIENTIFIC PROGRAM

ORAL PRESENTATIONS

Monday, 21st September, Morning Session

Theme 1: Active/Passive continental margins

Chairpersons: *S. Klemperer* and *J.C. Sibuet*

8:30 WELCOME

8:50 K. Hinz (Invited presentation) and BGR's Marine Geophysical Group
NATURE AND ORIGIN OF CONVERGENT MARGINS WITH A VOLUMINOUS, WEDGE-SHAPED ROCK BODY - STILL AN ENIGMA

9:20 J.C. Sibuet, S. Srivastava, H. Nouzé, V. Louvel and J.P. Le Formal
GALICIA BANK-FLEMISH CAP CONJUGATE MARGINS

9:40 D.S. Sawyer, C.A. Zelt, T. Reston, J.A. Austin Jr. and the Science Party of R/V Maurice Ewing Cruise 97-05
A NEW VIEW OF THE GALICIA S REFLECTOR: ISE-97 RESULTS

10:00 M. Laigle, R. Nicolich, A. Hirn, L. Cernobori and J. Gallart
CRUSTAL STRUCTURE OF THE IONIAN MARGIN OF SICILY AND ETNA VOLCANO

10:20 N. Vidal, D. Klaeschen, A. Kopf, C. Docherty, R. Von Huene and V. Krasheninnikov
SEISMIC IMAGES OF THE CONVERGENCE ZONE FROM SOUTH OF CYPRUS TO THE SYRIAN COAST, EASTERN MEDITERRANEAN

10:40 DISCUSSION

10:50 COFFEE BREAK

11:10 J.J. Dañobeitia, D. Córdoba, R. Bartolomé, F. Michaud, R. Carbonell, D. Graindorge and L. Delgado-Argote
CRUSTAL STRUCTURE AT THE CONTACT BETWEEN THE RIVERA PLATE AND THE JALISCO BLOCK (WEST COAST OF MEXICO)

11:30 D.W. Scholl, R. von Huene, C.R. Ranero, and P. Vannucchi
DEEP REFLECTION IMAGING AND DRILLING AT CONVERGENT MARGINS PERSIST IN DOCUMENTING SUBDUCTION-CAUSED EROSION OF UPPER PLATE LITHOSPHERE: NEW EXAMPLE FROM COSTA RICA AND THE BROADER IMPLICATIONS FOR INTERPRETING SEISMIC IMAGES OF ANCIENT OROGENIC BELTS ARCS

11:50 C.R. Ranero, R. Von Huene, E. Flueh, M. Duarte and D. Baca
STRUCTURE OF THE CONTINENTAL CONVERGENT PACIFIC MARGIN OF NICARAGUA

12:10 O. Oncken, S. Sobolev, E. Lueschen, S. Lueth and P. Giese
ANCORP'96: IMAGE OF ACTIVE DEHYDRATION OF THE SUBDUCTING NAZCA PLATE IN THE CENTRAL ANDES

12:30 C. Reichert and CINCA study group
THE EROSION SUBDUCTION PROCESS OFF NORTH CHILE DERIVED FROM CINCA GEOPHYSICAL AND GEOLOGICAL DATA

12:50 DISCUSSION

13:15 LUNCH

Monday, 21st September, Afternoon Session

Chairpersons: *B. Drummond* and *W.S. Holbrook*

15:00 J. Sayers and C.D.N. Collins
THE CRUSTAL STRUCTURE OF A PASSIVE MARGIN: A TRANSECT ACROSS THE AUSTRALIAN NORTH WEST SHELF

15:20 J. M. Lorenzo, G. O'Brien, J. Stewart and K. Tandon
INELASTIC BEHAVIOR OF THE LITHOSPHERE AND ITS CONTROL ON FORELAND BASIN DEVELOPMENT: NORTH WEST SHELF OF AUSTRALIA, TIMOR SEA

15:40 C.-S. Liu, P. Schnurle, S. Lallemand and D.L. Reed
CRUSTAL STRUCTURES OF THE PHILIPPINE SEA PLATE NEAR TAIWAN ARC-CONTINENT COLLISION ZONE

16:00 COFFEE BREAK

16:30 B. Della Vedova, F. Accaino, L. Cernobori, G. Pellis, L. Petronio, C. Rinaldi, M. Romanelli, A. Tassone and the TENAP Group
CRUSTAL STRUCTURE OF THE NORTHERN TIP OF THE ANTARCTIC PENINSULA FROM WIDE-ANGLE AND NORMAL INCIDENCE SEISMIC DATA

16:50 A. Maldonado, N. Zitellini, G. Leitchenkov, J.C. Balany, F. Coren, J. Galindo-Zaldívar, E. Lodolo, A. Jabaloy, C. Zanolla, J. Rodríguez-Fernández and O. Vinnikovskaya

BASIN DEVELOPMENT ALONG THE SCOTIA/ANTARCTICA PLATE BOUNDARY (NORTHERN WEDDELL SEA)

17:10 S. Kodaira, J-O. Park, H. Amano, N. Takahashi, Y. Kaneda, T. Tsuru, M. Shinohara and K. Mochizuki

DEEP SEISMIC IMAGING OF THE NANKAI TROUGH SEISMOGENIC ZONE FROM MULTICHANNEL AND OCEAN-BOTTOM SEISMIC DATA

17:30 T. Ikawa, Y. Yusa, K. Takemura and T. Ito

MARINE SEISMIC PROFILING ACROSS THE BEPPU BAY, NORTHEASTERN EXTREME OF THE BEPPU-SHIMABARA GRABEN, SOUTHWEST JAPAN

17:50 DISCUSSION

18:15 POSTER SESSION

20:15 DINNER

22:00 OPEN SESSION - 1: *A GLOBAL COMMITTEE ON LITHOSPHERIC TRANSECTS (COLT)*

Chairpersons: *L. Brown, O. Onken and B. Drummond*

Deep seismic profiling evolved during the 70's and 80's from the isolated experiments of a few pioneers into a diverse, multidisciplinary ensemble of national programs of lithospheric exploration. The 90's has seen the emergence of multinational collaborations as a dominant mode of such research. As the millennium approaches, a more comprehensive global approach to deep exploration is under consideration. Based on recommendations arising from the last Deep Seismix Symposium in Asilomar, a new committee under ILP sponsorship is being formed to stimulate, facilitate and coordinate a new generation of deep lithospheric studies cored by seismic profiling. Issues to be discussed in Barcelona are the purview, priorities, composition, and mode of operation of this new body.

Tuesday, 22st September, Morning Session

Theme 1: Active/Passive continental margins (continued)

Chairperson: *H. Thybo*

8:30 R. von Huene and D. Klaeschen
COSEISMIC AND INTRASEISMIC STRAIN ACROSS THE KODIAK MARGIN, ALASKA

8:50 T. Ito, N. Tsumura, K. Arita, H. Ikawa, T. Ikawa, N. Shimizu and T. Ikawa
DELAMINATION-WEDGE STRUCTURE BENEATH THE HIDAKA ARC-ARC COLLISION ZONE, CENTRAL HOKKAIDO, JAPAN

9:10 H. Sato, N. Hirata, T. Iwasaki, Y. Ikeda, T. Ito, T. Imaizumi and T. Ikawa
DEEP TO SHALLOW SEISMIC REFLECTION PROFILING ACROSS THE ACTIVE SENYA FAULT, NORTHERN HONSHU, JAPAN

9:30 N. Hirata, A. Hasegawa, N. Umino, H. Sato, T. Iwasaki and J. Kasahara
INTEGRATED SEISMIC PROFILING ACROSS THE NORTHEASTERN HONSHU ARC, JAPAN

9:50 DISCUSSION

Theme 2: Integrated multidisciplinary studies (wide-aperture seismics, earthquake tomography, magnetotellurics, ...)

Chairperson: *J.C. Bean*

10:00 S. B. Smithson (Invited presentation), F. Wenzel and Y. Ganchin
REFLECTIVITY AND VELOCITY AT KOLA AND KTB SUPERDEEP BOREHOLES

10:30 COFFEE BREAK

11:00 A. Hirn (Invited presentation)
REFLECTION, REFRACTION AND EARTHQUAKE TOMOGRAPHY: EXAMPLES FROM ETNA VOLCANO AND GREEK SEISMOGENIC ZONES

11:30 A. Tryggvasson, S.Th. Rögnvaldsson and H.M. Benz

SEISMIC TRAVEL TIME TOMOGRAPHY STUDIES OF TWO VOLCANOES, THE LONG VALLEY CALDERA, CALIFORNIA, AND THE HENGILL VOLCANO, ICELAND

11:50 G. F. West
WHAT ARE CRUSTAL SEISMIC SURVEYS TELLING US?

12:10 A. Meltzer, G. Sarker, S. Park, P. Zeitler, P. Koons, D. Craw, P. Chamberlain, L. Seeber, J. Armbruster, M. Edwards, B. Kidd, D. Schneider and R. Mackie
CRUSTAL REWORKING DURING OROGENY: AN ACTIVE-SYSTEM HIMALAYAN PERSPECTIVE

12:30 Tim Stern, D. Okaya, T. Henyey, F. Davey, S. Holbrook and S.I. Working Group
SEISMIC EXPLORATION OF A CONTINENTAL TRANSPRESSIONAL PLATE BOUNDARY: THE SOUTH ISLAND OF NEW ZEALAND

12:50 DISCUSSION

13:15 LUNCH

Tuesday, 22st September, Afternoon Session

Theme 3: Imaging 2D and 3D heterogeneities and anisotropy

Chairpersons: *R. Carbonell* and *C. Juhlin*

15:00 A. Levander (Invited presentation)
THE STOCHASTIC CRUST AND ITS SEISMIC RESPONSE

15:30 C. A. Hurich and A. Kocurko
STATISTICAL APPROACHES TO INTERPRETING DEEP SEISMIC DATA

15:50 H. Douma and K. Roy-Chowdhury
THE IMPORTANCE OF MULTIPLE SCATTERING IN 1D BIMODAL FRACTAL MEDIA: IMPLICATIONS FOR IMAGING THE CONTINENTAL LOWER CRUST

16:10 COFFEE BREAK

16:40 H.Thybo, T.Abramovitz and M.Laigle
A TECTONIC MANTLE SHEAR ZONE IN THE SOUTHEASTERN NORTH SEA INTERPRETED FROM MONA LISA DEEP SEISMIC DATA

17:00 R. W. Hobbs, A. Wild and J. Andriatsitohaina
FAST FULL-ELASTIC 3-D MODELLING OF COMPLEX GEOLOGICAL STRUCTURES

17:20 T. M. Hansen, S. C. Singh and B. H. Jacobsen
SENSITIVITY OF THE SEISMIC WIDE ANGLE WAVE FIELD AND FIRST ARRIVAL TIMES TO FINE SCALE CRUSTAL STRUCTURE

17:40 M. Nedimovic, W. Wang and G. F. West
FOCUSSING PROBLEMS IN REFLECTION IMAGING OF THE CRUST

18:00 DISCUSSION

18:30 POSTER SESSION

20:15 DINNER

21:30 OPEN SESSION - 2: *NEW TECHNOLOGIES, NEW APPLICATIONS, NEW INTERPRETATIONS, NEW EXPERIMENT DESIGNS*

Chairpersons: *R. Hobbs, A. Green and A. Levander*

Several advances in technologies recently introduced in oil-industry reflection seismic surveying will undoubtedly be considered for adoption by the mainstream deep reflection seismology community. Some topics that may be debated in this session are: (i) ultra-wide and ultra-long marine streamer arrays, (ii) pseudo or true 3-D seismic surveying, (iii) 3-component full wave recording, and (iv) timelapse experiments, (v) logistics of deep seismic investigations in remote areas, (vi) inversion and modeling of full wave fields.

22:15 OPEN SESSION - 3: *FUTURE ACTIVITIES AND FORMAT OF THE CCSS AND RELATED WORKSHOPS*

Chairpersons: *W. Mooney, K. Prodehl and D. Snyder*

As we all know, the format of CCSS Workshops is considered a valuable one by many (particularly younger seismologists), however it now puts too much demand on our time. Nevertheless, topics like: (i) data and software epositories, (ii) world wide seismic instrumentation, (iii) interpretation and modeling tools, that are generally discussed in these workshops need to be addressed by the Earth Science community. Perhaps a new format for the workshops would make them more efficient and valuable such as: incorporating it into other meetings for example the Deep Seismic Profiling of the Continents; "interactive workshops" where attendees sent software in advance to be installed on a super computer facility. It then could be used by all participants during the workshop on common or similar data sets.

Wednesday, 23st September, Morning Session

Theme 4: Intra-continental collisions

Chairpersons: *A. Pérez-Estaún* and *A. Levander*

8:30 Frederick A. Cook (Invited presentation)
COLLISIONS, CONTINENTS AND REFLECTIONS FROM THE LITHOSPHERE

9:00 B.J. Drummond, T. Fomin, J. Leven and G.Gibson
MULTIPLE EPISODES OF CRUSTAL DEFORMATION IN A BROAD ZONE SPANNING THE BOUNDARY BETWEEN THE SHIELD AND YOUNGER TERRANES IN SE AUSTRALIA

9:20 I. B. Morozov , J. Chen, S. B. Smithson and L. S. Hollister
CRUSTAL STRUCTURE ACROSS THE COAST MOUNTAINS, SE ALASKA

9:40 G.M. Ross, D.W. Eaton and D. Boerner
REFLECTIONS ON ASSEMBLY OF WESTERN LAURENTIA: THE ROLE OF TECTONIC BOUNDARY CONDITIONS

10:00 D. Eaton and A. Hynes
EXTRUSION TECTONICS IN THE GRENVILLE PROVINCE: SEISMIC, GRAVITY AND STRUCTURAL CONSTRAINTS ON EXHUMATION OF THE OROGENIC ROOT

10:20 DISCUSSION

10:30 COFFEE BREAK

11:00 D. B. Snyder, R. W. Hobbs and the Chicxulub Working Group
RINGED STRUCTURAL ZONES WITH DEEP ROOTS FORMED BY THE CHICXULUB IMPACT

11:20 M. Warner and J. Morgan
CHICXULUB SEISMIC EXPERIMENT: DEEP IMPACT - THE REAL STORY

11:40 A. Teixell
NEW INSIGHTS ON THE COLLISIONAL STRUCTURE OF THE PYRENEES FROM ECORS-ARZACQ SEISMIC REFLECTION DATA

12:00 J. Pous, P. Queralt, A. Marcuello and J. Ledo
MAGNETOTELLURIC STUDIES IN THE IBERIAN PENINSULA

12:20 A.R. Ross, L.D. Brown and K. D. Nelson
BRIGHT SPOTS AND GRANITIC MELTS IN SOUTHERN TIBET

12:40 N. Balling
SEISMIC REFLECTORS IN THE MANTLE LITHOSPHERE BENEATH THE BALTIC SHIELD AND NORTHERN TORNQUIST ZONE AND TECTONIC IMPLICATIONS

13:00 DISCUSSION

13:10 LUNCH

14:30 VISIT TO BARCELONA INCLUDING DINNER

Thursday, 24st September, Morning Session

Theme 5: Transects and syntheses: seismic signatures of Precambrian shields, Alpine versus Variscan orogens in Eurasia, ...

Chairpersons: *L.D. Brown* and *R. Clowes*

8:30 O. Oncken (Invited presentation)
THE SEISMIC FABRIC OF OROGENIC BELTS AND ITS MEANING-CONSTRAINTS FROM EURASIAN OROGENS

9:00 W.D. Mooney and D. Abbott
THE FORMATION OF CONTINENTAL CRUST AND LITHOSPHERE: A SYNTHESIS BASED ON SEISMIC REFLECTION PROFILING AND GEOLOGIC OBSERVATIONS

9:20 C. Truffert, A. Bitri, P. Guennoc and J.P. Brun
DEEP SEISMIC IMAGING OF THE CADOMIAN THRUST WEDGE OF NORTHERN BRITTANY - GEOFRANCE 3D PROGRAM

9:40 N.I. Pavlenkova
SEISMIC BOUNDARIES IN THE UPPERMOST MANTLE OF THE NORTHERN EURASIA

10:00 B.R. Goleby, B.J. Drummond, A. Owen, N. Archibald and R. Bateman
EXTRACTING MORE DETAIL FROM REGIONAL TRANSECTS: AN ARCHEAN GREENSTONE EXAMPLE

Evidence for major crustal shortening in the eastern goldfields of W.A.

10:20 DISCUSSION

10:30 COFFEE BREAK

11:00 L.D. Brown
SEISMIC STRATIGRAPHY OF THE CONTINENTAL LITHOSPHERE

11:20 C.C. Diaconescu and J.H. Knapp
THE ROLE OF A PHASE-CHANGE MOHO IN STABILIZATION AND PRESERVATION OF THE SOUTHERN URALIAN OROGEN, RUSSIA

11:40 H. P. Echtler, M. Stiller and the URSEIS Research Group
THE SOUTHERN URALS TRANSECT - URSEIS '95 - PRESERVATION AND ORIGIN OF PALEOZOIC COLLISIONAL FABRICS

12:00 R. Carbonell, J. Gallart, D. Brown and A. Pérez-Estaún
THE MOHO BENEATH THE SOUTHERN URALS MAPPED BY PmP AND SmS PHASE

12:20 Y. Makovsky and S. L. Klemperer
MEASURING THE SEISMIC PROPERTIES OF TIBETAN BRIGHT SPOTS: EVIDENCE FOR FREE AQUEOUS FLUIDS IN THE TIBETAN MIDDLE CRUST

12:40 DISCUSSION

13:15 LUNCH

Thursday, 24st September, Afternoon Session

Chairperson: *W.D. Mooney*

15:00 R.M. Clowes
LITHOPROBE: RECENT RESULTS AND FUTURE PLANS FOR REVEALING THE EVOLUTION OF A CONTINENT

15:20 Z. Hajnal, B. Nemeth, J. Lewry, S. Lucas and D. White
REGIONALLY VARIANT SEISMIC IMAGES OF THE WESTERN MARGIN OF THE TRANS-HUDSON OROGEN

15:40 D. White, H. Helmstaedt, R. Harrap, P. Thurston, A. van der Velden, K. Hall and D. Davis
ACCRETIONARY TECTONICS IN THE LATE ARCHEAN? FIRST RESULTS FROM THE LITHOPROBE WESTERN SUPERIOR TRANSECT

16:00 COFFEE BREAK

Theme 6: Seismic reflection applications to natural resources and enviroment

Chairperson: *R.W. Hobbs*

16:30 A. Green (Invited presentation), F. Buker, K. Holliger, H. Horstmeyer, H.R. Maurer, F. Nitsche, M. Roth, R. Spitzer, and M. Van der Veen
RECENT INNOVATIONS IN ENGINEERING-SCALE SEISMIC REFLECTION SURVEYING

17:00 J.H. McBride and D.R. Kolata
PROGRESS IN STUDYING PRECAMBRIAN CRUST BENEATH CONTINENTAL INTERIORS FROM SEISMIC REFLECTION: USA MIDCONTINENT

17:20 B. Milkereit and E. Adam
3D SEISMIC PROFILING FOR MINERAL EXPLORATION

17:40 DISCUSSION

18:20 POSTER SESSION

20:30 BANQUET

Friday, 25st September, Morning Session

Theme 7: Seismic techniques: new developments

Chairperson: *A. Green*

8:30 R. W. Hobbs (Invited presentation)
DEVELOPMENT AND FUTURE OF IMAGING THE LITHOSPHERE

9:00 J. Morgan and M. Warner
FULL -WAVEFIELD SEISMIC INVERSION - BEYOND RAY-TRACING

9:20 C.J. Bean, D. Marsan and F. Martini
ESTIMATING THE STATISTICS OF CRUSTAL REFLECTIVITY: THE ROLE OF SEISMIC BANDWIDTH

9:40 P. J. Barton and R. A. Edwards
A NEW METHOD FOR ANALYSING DENSELY-SAMPLED WIDE-ANGLE SEISMIC DATA

Theme 8: Rifts, basins and extensional provinces

Chairperson: *D.B. Snyder*

10:00 D.S. Sawyer (Invited presentation)
RIFTS, BASINS AND EXTENSIONAL PROVINCES

10:30 COFFEE BREAK

11:00 M.B. Magnani, M.R. Barchi, G. Minelli and G. Pialli
EXTENSIONAL TECTONICS AND CRUSTAL REFLECTIVITY: THE EXAMPLE OF THE NORTHERN APENNINES (ITALY)

11:20 A.Guterch, M.Grad, H.Thybo and R.Keller
POLONAISE'97- SEISMIC PENETRATION INTO LITHOSPHERE OF THE POLISH BASIN

11:40 A.V. Egorkin
DEEP STRUCTURE OF THE NORTHEASTERN PART OF THE EAST-EUROPEAN CRAT

12:00 B.J. Drummond, R.J. Korsch, T.J. Barton, N. Rawlinson, A.V. Brown and A.N.Yeates
A NEW PASSIVE MARGIN MODEL FOR THE NEOPROTEROZOIC AND EARLY PALAEO OF SE AUSTRALIA DERIVED FROM SEISMIC STUDIES OF TASMANIA

12:20 DISCUSSION and CLOSING REMARKS

13:00 LUNCH

14:30 DEPARTURE TO BARCELONA AIRPORT

SCIENTIFIC PROGRAM

POSTER PRESENTATIONS

Theme 1: Active/Passive continental margins

T1-01 A.G. Goncharov, C.D.N. Collins, T.N. Fomin, P. Petrovic, V. Pilipenko and B.G. Drummond
INTEGRATED OCEAN-BOTTOM SEISMOGRAPH AND CONVENTIONAL REFLECTION STUDIES IN THE PETREL SUB-BASIN AT THE AUSTRALIAN NORTH WEST SHELF

T1-02 A.Y. Kritsky, R.D. Müller, C.D.N. Collins, H. Stagg and G.I. Christeson
VELOCITY STRUCTURE OF THE ARGO ABYSSAL PLAIN, NORTH WEST SHELF OF AUSTRALIA

T1-03 J. Sayers and C.D.N. Collins
THE CRUSTAL STRUCTURE OF A PASSIVE MARGIN: A TRANSECT ACROSS THE AUSTRALIAN NORTH WEST SHELF

T1-04 H.M.J. Stagg, P.A. Symonds and D.C. Ramsay
CONTINENTAL MARGIN TRANSECTS IN THE CENTRAL GREAT AUSTRALIAN BIGHT

T1-05 H.M.J. Stagg and A.M.G. Moore
CRUSTAL STRUCTURE UNDERPINNING THE OTWAY BASIN, SOUTHEAST AUSTRALIA: A PASSIVE MARGIN BASIN IN A STRIKE-SLIP SETTING

T1-06 P. Petkovic and C.D.N. Collins
VELOCITY MODEL BETWEEN TIMOR AND AUSTRALIA FROM SEISMIC AND GRAVITY DATA

T1-07 N. Rawlinson, T.O. Semenova, C.D.N. Collins, G.A. Houseman and B.J. Drummond
CRUSTAL STRUCTURE IN NORTHERN AND EASTERN TASMANIA FROM SEISMIC REFRACTION DATA

T1-08 C.-S. Liu, P. Schnurle, S. Lallemand and D.L. Reed
CRUSTAL STRUCTURES OF THE PHILIPPINE SEA PLATE NEAR TAIWAN ARC-CONTINENT COLLISION ZONE

T1-09 D.L. Reed, T. Nguyen, W.C. Chi, N. Lundberg, G. F. Moore, Y. Nakamura, K. McIntosh and C.-S. Liu
FOREARC GROWTH AND BASIN COLLAPSE IN THE TAIWAN COLLISION

T1-10 T. Ikawa, T. Ito, H. Sato, T. Ikawa and S. Okuike
WEST-VERGENT FOLD-AND-THRUST BELT IN THE FRONT OF THE HIDAKA COLLISION ZONE, HOKKAIDO, JAPAN

T1-11 T. Ikawa, Y. Yusa, K. Takemura and T. Ito
MARINE SEISMIC PROFILING ACROSS THE BEPPU BAY, NORTHEASTERN EXTREME OF THE BEPPU-SHIMABARA GRABEN, SOUTHWEST JAPAN

T1-12 M. Ando, T. Moriya and Research Group for Explosion seismology of Japan
ACCRETION DEVELOPMENT STRUCTURE BENEATH KYUSHU ISLAND, JAPAN, DEDUCED FROM A SEISMIC REFRACTION AND WIDE ANGLE REFLECTION EXPERIMENT

T1-13 Y. Kaneda, S. Kodaira, T. Tsuru, J. Park, N. Takahashi, H. Kinoshita and Y. Kono
TOWARD UNDERSTANDING OF SUBDUCTION EARTHQUAKES: - JAMSTEC SEISMIC STUDY IN SEISMOGENIC ZONES -

T1-14 H. Sato, N. Hirata, T. Iwasaki, Y. Ikeda, T. Ito, T. Imaizumi and T. Ikawa
DEEP TO SHALLOW SEISMIC REFLECTION PROFILING ACROSS THE ACTIVE SENYA FAULT, NORTHERN HONSHU, JAPAN

T1-15 T. Iwasaki, W. Kato, T.Takeda, S. Sekine, T. Moriya N. Umino,T. Okada A. Hasemi, K. Miyashita, T.Mizogami, T. Matsushima, K. Tashiro and H. Miyamachi
CRUSTAL STRUCTURE ACROSS THE NORTHERN HONSHU ARC, JAPAN, AS REVEALED FROM A WIDE-ANGLE SEISMIC EXPERIMENT

T1-16 T. Yokokura, T. Miyazaki, N. Kano and K. Yamaguchi
DEEP STRUCTURE AROUND AN EARTHQUAKE SWARM AREA, MIYAGI PREFECTURE, NORTHEASTERN JAPAN

T1-17 E. Rubio, M. Torné, E. Vera and C. Ranero
THE SOUTHERMOST CHILEAN MARGIN: INSIGHTS FROM PRE-STACK DEPTH MIGRATION AND 2D GRAVITY MODELING

T1-18 A.M. Hojka, C.A. Zelt and E.R. Flueh
3D VELOCITY STRUCTURE ABOVE THE SUBDUCTING JUAN FERNANDEZ RIDGE OFFSHORE CENTRAL CHILE

T1-19 C. Reichert and CINCA study group
THE EROSION SUBDUCTION PROCESS OFF NORTH CHILE DERIVED FROM CINCA GEOPHYSICAL AND GEOLOGICAL DATA

T1-20 V. Sallarès, J. J. Dañobeitia, E. Flueh and G. Leandro
CRUSTAL STRUCTURE OF SOUTHERN MIDDLE AMERICAN LANDBRIDGE: NEW INSIGHTS FROM COMBINED SEISMIC PROFILING AND LOCAL EARTHQUAKES TOMOGRAPHY IN COSTA RICA

T1-21 D.W. Scholl, R. von Huene, C.R. Ranero and P. Vannucchi
DEEP REFLECTION IMAGING AND DRILLING AT CONVERGENT MARGINS PERSIST IN DOCUMENTING SUBDUCTION-CAUSED EROSION OF UPPER PLATE LITHOSPHERE: NEW EXAMPLE FROM COSTA RICA AND THE BROADER IMPLICATIONS FOR INTERPRETING SEISMIC IMAGES OF ANCIENT OROGENIC BELTS AND ARCS

T1-22 C.R. Ranero, R. Von Huene, E. Flueh, M. Duarte and D. Baca
STRUCTURE OF THE CONTINENTAL CONVERGENT PACIFIC MARGIN OF NICARAGUA

T1-23 R. Bartolomé, D. Graindorge, J.J. Dañobeitia, D. Córdoba, J.P. Canales, J. Diaz,J. Gallart, L. Delgado-Argote and Ph. Charvis
CRUSTAL EVOLUTION FROM THE SOUTHERN MARGIN OF BAJA CALIFORNIA PENINSULA TO THE JALISCO BLOCK (WEST MEXICO)

T1-24 M. Gerdom, A. Trehu, E. R. Flueh and D. Klaeschen
THE CONTINENTAL MARGIN OFF OREGON FROM SEISMIC INVESTIGATIONS

T1-25 T. Parsons
REFLECTIONS FROM A DEEP RIGHT-LATERAL STRIKE-SLIP FAULT ZONE

T1-26 P.E. Hart, T. Parsons, R. Stiller and J.R. Childs
BASIX III: REFLECTION DATA INTERPRETATIONS FROM THE 1997 SAN FRANCISCO BAY AREA SEISMIC IMAGING EXPERIMENT

T1-27 T.J. Henstock and A. Levander
TECTONIC UNDERPLATING OF GORDA CRUST IN THE MENDOCINO TRIPLE JUNCTION REGION, NORTHERN CALIFORNIA

T1-28 D.S. Sawyer
LITHOSPHERE RHEOLOGY AND THE FORMATION OF OCEANIC MEGAMULLIONS AND METAMORPHIC CORE COMPLEXES

T1-29 D.S. Sawyer, C.A. Zelt, T. Reston, J.A. Austin Jr. and the Science Party of R/V Maurice Ewing Cruise 97-05
A NEW VIEW OF THE GALICIA S REFLECTOR: ISE-97 RESULTS

T1-30 C.A. Zelt, D.S. Sawyer, T. Reston and Y. Nakamura
2D AND 3D VELOCITY STRUCTURE OF THE IBERIA MARGIN FROM THE INVERSION OF WIDE-ANGLE TRAVELTIME DATA

T1-31 M. Perez-Gussinye, C.R. Ranero, T.J. Reston, E. Flueh and D. Sawyer
THE STRUCTURE OF THE GALICIA INTERIOR BASIN, WEST OF IBERIA

T1-32 G. Grandjean, M. Recq, P. Andréo and P. Guennoc
REFRACTION/WIDE ANGLE REFLECTION INVESTIGATION OF THE CADOMIAN CRUST BETWEEN NORTHERN BRITTANY AND THE CHANNEL ISLANDS

T1-33 Discovery 215 Working Group
T. A. Minshull, S. M. Dean, R. B. Whitmarsh, S. M. Russell, K. E. Louden and D. Chian
EXHUMED MANTLE AT THE OCEAN-CONTINENTAL TRANSITION IN THE SOUTHERN IBERIA ABYSSAL PLAIN

T1-34 D. Córdoba, J.J. Dañobeitia and the ESIGAL WG
DEEP CRUSTAL STRUCTURE FROM THE GALICIA INTERIOR BASIN TO THE HERCYNIAN MASSIF

T1-35 A. González, D. Córdoba, M. Torné, L.M. Matias and D. Vales
SEISMIC AND GRAVITY STRUCTURE OF ATLANTIC IBERIAN MARGINS: GALICIA, HORSESHOE ABYSSAL PLAIN AND GULF OF CADIZ

T1-36 M. Torné, R. Carbonell, D. Tortella, A. González, D. Córdoba, A. Pérez-Estaún and I. Marzán
CRUSTAL VIEWS OF THE GORRINGE BANK REGION AND GULF OF CADIZ: THE IAM PROJECT

T1-37 J. Álvarez-Marrón, N. Vidal, M. Comas and J.J. Dañobeitia
SEISMIC CONFIGURATION OF THE BETIC-ALBORAN OROGEN IN N-S AND E-W TRANSECTS

T1-38 C. Clément, M. Sachpazi, A. Hirn, Ph. Charvis, Y. Hello, J.C. Lépine and N. Roussos
SEISMIC STRUCTURE AND THE ACTIVE HELLENIC SUBDUCTION IN THE IONIAN ZONE

T1-39 C. Kopp, J.Frühn, E. R. Flueh, C. Reichert, N. Kukowski and D. Klaeschen
SEISMIC INVESTIGATIONS OF THE MAKRAN ACCRETIONARY WEDGE

Theme 2: Integrated multidisciplinary studies (wide-aperture seismics, earthquake tomography, magnetotellurics, ...)

T2-01 T. S. Clark, S. B. Smithson and C. R. Bentley
CRUSTAL REFLECTION-REFRACTION PROFILE OF THE BYRD SUBGLACIAL BASIN, ANTARTICA

T2-02 T. Henyey, T. Stern, F. Davey, D. Okaya and the S.I. Working Group
GEOPHYSICAL INVESTIGATION OF A MODERN CONTINENTAL TRANS-RESSIONAL OROGEN: SOTUHERN ALPS, NEW ZEALAND

T2-03 F. J. Davey, N. J. Godfrey, A. Melhuish, D. Okaya and the SIGHT Working Group
CRUSTAL STRUCTURE AND DEFORMATION OF THE EASTERN PROVINCE (MESOZOIC TERRANES), SOUTHEASTERN SOUTH ISLAND, NEW ZEALAND

T2-04 S.A. Henrys, D. Okaya, A. Melhuish, T. Stern, S. Holbrook and SIGHT Group
NEAR-VERTICAL SEISMIC IMAGES OF A CONTINENTAL TRANS-PRESSIONAL PLATE BOUNDARY: SOUTHERN ALPS, NEW ZEALAND

T2-05 W.S. Holbrook, D. Okaya, T. Stern, A. Melhuish, F. Davey, S. Henrys, M. Scherwath and S. Kleffman
DEEP SEISMIC PROFILES ACROSS THE PACIFIC-AUSTRALIAN PLATE BOUNDARY, SOUTH ISLAND, NEW ZEALAND

T2-06 N. Hirata, H. Sato and M. Matsubara
DEEP SEISMIC IMAGING OF THE MT. TATEYAMA AND ITOIGAWA-SHIZUOKA TECTONIC LINE IN THE CENTRAL PART OF HONSHU, JAPAN

T2-07 P. Ayarza, C. Juhlin, D. Brown, M. Bliznetsov and A. Rybalka
NATURE OF THE SWALLOW REFLECTIVITY IN THE SG4 BOREHOLE AREA: CONSTRAINS ON THE STRUCTURE OF THE UPPER CRUST IN THE TAGIL SYNFORM (MIDDLE URALS)

T2-08 C. Ayala, G.S. Kimbell and R. Carbonell
INTEGRATED MODELLING OF THE LITHOSFERIC STRUCTURE OF THE SOUTHERN URALS USING QUASIGEOID, GRAVITY, MAGNETIC AND SEISMIC DATA

T2-09 J. Yliniemi, K. Komminaho, I.A. Sanina, O.Y. Riznichenko and B.M. Shoubik
A MORE COMPLETE WIDE-ANGLE VELOCITY MODEL FOR THE NOTHERN PART OF THE BOTHNIAN BAY

T2-10 L. Nielsen, N. Balling and B.H. Jacobsen
INTEGRATED WIDE-ANGLE SEISMIC AND GRAVITY INVERSION FOR CRUSTAL STRUCTURE BENEATH THE CENTRAL GRABEN, NORTH SEA

T2-11 V. Raileanu
INTERPRETATION OF THE SEISMIC AND RHEOLOGICAL DATA WITHIN AND IN FRONT OF THE EASTERN CARPATHIANS BEND AREA

T2-12 K. J. Lielke, C. Tomek and S. B. Smithson
SEISMIC AND GRAVITY STUDIES OF TWO CONTRASTING GRANITES IN THE CZECH REPUBLIC

T2-13 J. Ledo and A.G. Jones
ELECTRICAL CONDUCTIVITY STRUCTURES OF THE SOUTHERN CANADIAN CORDILLERA AND ITS RELATIONSHIP WITH OTHER GEOPHYSICAL AND GEOLOGICAL DATA

T2-14 J. Ledo, A.G. Jones and X. Garcia
ON THE NACP CONDUCTIVITY ANOMALY GEOPHYSICAL SIGNATURE

T2-15 P.T.C. Hammer, R.M. Clowes and R.M. Ellis
CRUSTAL STRUCTURE ACROSS THE CORDILLERAN OROGEN OF NORTHWEST BRITISH COLUMBIA FROM LITHOPROBE AND ACCRETE SEISMIC DATA

T2-16 C.E. Lynn, K.W. Hall and F.A. Cook
COMPARATIVE ANALYSES OF REGIONAL GEOLOGICAL AND GEOPHYSICAL DATA SETS BY APPLICATION OF GEOGRAPHICAL INFORMATION SYSTEMS

T2-17 K.W. Hall, F.A. Cook and C.E. Lynn
WAVENUMBER FILTERED POTENTIAL FIELD ANOMALIES OF WESTERN CANADA

T2-18 V. Sallarés, R. Carbonell, J.J. Dañobeitia, J. Pous and V. García Dueñas
A MULTIDISCIPLINARY VIEW OF LITHOSPHERE IN THE BETICS AREA (SOUTHERN SPAIN)

T2-19 E. Gurria and J. Mezcua
CRUSTAL AND UPPER MANTLE VELOCITY STRUCTURE OF THE BETICS AND ALBORAN SEA REGION

T2-20 Mª J. Jurado, F. Wenzel, R. Carbonell and M. Tittgemayer
CRUSTAL REFLECTIVITY AT THE KTB SUPERDEEP HOLE: NEW INSIGHTS FROM WELL LOG DATA

T2-21 I. Tchebotareva
EMISSION TOMOGRAPHY. STUDY OF STRUCTURE AND EMISSION ACTIVITY OF THE CRUST BENEATH VOLCANIC AREA IN NORTHERN KANTO, JAPAN

Theme 3: Imaging 2D and 3D heterogeneities and anisotropy

T3-01 M. Tittgemeyer, F. Wenzel, S. Sobolev and K. Fuchs
WHAT ARE PN VELOCITIES TELLING US ?

T3-02 L.M. La Flame, T.J. Henstock, C. Zelt and A. Levander
THE BASIN AND RANGE REVISITED

T3-03 I. B. Morozov, S. B. Smithson and L. S. Hollister
ANALYSIS OF UNUSUALLY HIGH-QUALITY SHEAR-WAVE WIDE-ANGLE RECORDS FROM ACCRETE EXPERIMENT, SE ALASKA

T3-04 I.A. Sanina, V.G. Markin and A.L. Ushakov
RESOLUTION PROPERTIES OF A BABEL SECTION (LINES 1, 6, 7) AND 3-D RECONSTRUCTION FROM EXPANDED WIDE-ANGLE DATA

T3-05 C.A. Zelt
ESTIMATING THE RESOLUTION OF VELOCITY FROM 3D SEISMIC REFRACTION DATA

T3-06 J. Díaz and J. Gallart
SUBCRUSTAL SEISMIC ANISOTROPY BENEATH THE IBERIAN PENINSULA: A REVIEW

T3-07 N. J. Godfrey, N. I. Christensen, W. S. Holbrook, D. Okaya and R. Smith
THE EFFECTS OF VELOCITY ANISOTROPY ON SEISMIC REFRACTION DATA AND ITS ANALYSIS: AN EXAMPLE FROM SOUTH ISLAND, NEW ZEALAND

Theme 4: Intra-continental collisions

T4-01 S. Haines and S. Klemperer, on behalf of "INDEPTH III Science Team"
INDEPTH III: PRELIMINARY RESULTS FROM 1998 SEISMIC REFLECTION SURVEY ACROSS THE BANGGONG-NUJIANG SUTURE, CENTRAL TIBET

T4-02 Y. Wencai
DEEP SEISMIC PROFILING AND TECTONIC EVOLUTION OF SULU UHPM TERRANE, EAST-CENTRAL CHINA

T4-03 D. B. Snyder, R. W. Hobbs and the Chicxulub Working Group
CRUSTAL-SCALE STRUCTURAL GEOMETRIES OF THE CHICXULUB IMPACT FROM BIRPS SEISMIC REFLECTION PROFILES

T4-04 A.J. van der Velden and F.A. Cook
PROTEROZOIC AND CENOZOIC SUBDUCTION COMPLEXES: A COMPARISON OF GEOMETRIC FEATURES

T4-05 G.F. West
THE KAPUSKASING STRUCTURAL ZONE: A PROTEROZOIC MOUNTAIN-BUILDING EVENT ELUCIDATED BY MULTIDISCIPLINARY STUDIES

T4-06 B.J. Drummond, T. Fomin, J. Leven and G.Gibson
MULTIPLE EPISODES OF CRUSTAL DEFORMATION IN A BROAD ZONE SPANNING THE BOUNDARY BETWEEN THE SHIELD AND YOUNGER TERRANES IN SE AUSTRALIA

T4-07 J. Schmidt, U. Domaschk and E. Flueh
THE MONA LISA PROJECT - DEEP CRUSTAL SEISMIC MODELLING AND TECTONIC IMPLICATIONS

T4-08 A. Ribeiro
THE CONTINUATION OF TRANSFORM AND STRIKE-SLIP FAULTS INTO DEPTH: AN EXAMPLE FROM IBERIAN VARISCIDES

T4-09 R. Berzin, S. Kulakov and A. Souleimanov
GEOPHYSICAL INVESTIGATION OF THE JOINT BETWEEN PALEOZOIC DONBASS STRUCTURES AND KARPINSKY MOUNTAIN RIDGE

Theme 5: Transects and syntheses: seismic signatures of Precambrian shields, Alpine versus Variscan orogens in Eurasia, ...

T5-01 W.D. Mooney, G. Laske, T.G. Masters and K. Favret
THE HOW THICK IS THE EARTH'S CRUST?

T5-02 C.D.N. Collins, B.J.Drummond, B.R. Goleby and H.M.J. Stagg
THE STATUS OF CONTROLLED SOURCE DEEP SEISMIC RESEARCH IN AUSTRALIA

T5-03 B.J. Drummond and B.L.N. Kennett
THE AUSTRALIAN NATIONAL SEISMIC IMAGING RESOURCE (ANSIR): AN INITIATIVE TO FOSTER RESEARCH AND EDUCATION IN SEISMIC IMAGING IN AUSTRALIA

T5-04 A.G. Goncharov, B.J. Drummond, M.D. Lizinsky, C.D.N. Collins, T.N. Fomin, K.A. Kalnin and B.R. Goleby
BALANCED SEISMIC VELOCITY DISTRIBUTION IN THE PRECAMBRIAN CRUST OF THE BALTIC SHIELD AND AUSTRALIA AND ITS PETROLOGICAL IMPLICATIONS

T5-05 B.R. Goleby, R.I. Hackney, C. McA. Powell, M. Kneeshaw, D. Mason, D. Kepert ~~and B.J. Drummond~~
THE OPHTHALMIAN OROGENY, SYLVANIA DOME: RESOLUTION OF THE DEFORMATION EVENTS IN THE THIRD DIMENSION USING DEEP SEISMIC TECHNIQUES

T5-06 Y. Wang, X. Yuan, W.D. Mooney and R.G. Coleman
THE CRUSTAL STRUCTURE IN NORTHWEST CHINA

T5-07 L. Cai, Y. Baojun, L. Tiecheng, W. Shiyu, F. Xuan and H. Guangbing
THE SYNTHETIC RESEARCH OF SEISMIC SOUNDING DATA OF LINGBI-FENGXIAN IN THE EAST OF CHINA

T5-08 H.C. Tewari and V. Divakar Rao
GEOTRANSECTS ACROSS THE ARCHAEAN-PROTEROZOIC TERRAIN OF THE INDIAN SHIELD

T5-09 I. B. Morozov, E. A. Morozova, S. B. Smithson and L. N. Solodilov
CONSTRAINTS ON UPPER MANTLE P-WAVE ATTENUATION FROM THE NUCLEAR EXPLOSIONS OF THE RUSSIAN DEEP SEISMIC SOUNDING PROFILE "QUARTZ"

T5-10 E. A. Morozova, S. B. Smithson and L. N. Solodilov
UPPER MANTLE INVOLVEMENT IN REGIONAL TECTONICS FROM A COMBINED INTERPRETATION OF THE PNE PROFILE "QUARTZ," RUSSIAN EURASIA

T5-11 H. P. Echtler, M. Stiller and the URSEIS Research Group
THE SOUTHERN URALS TRANSECT - URSEIS '95 - PRESERVATION AND ORIGIN OF PALEOZOIC COLLISIONAL FABRICS

T5-12 Y. Makovsky, M. Stiller, D. L. Brown, J. Álvarez-Marrón R. Carbonell and A. Pérez-Estaún
CRUSTAL STRUCTURE OF THE FORELAND THRUST AND FAULT BELT OF THE SOUTHERN URALS FROM URSEIS EXPLOSIVE SEISMIC REFLECTION DATA

T5-13 P. Ayarza, D. Brown, J. Álvarez-Marrón, C. Juhlin and A. Tryggvason
CONTRASTING SEISMIC SIGNATURE OF ARC-CONTINENT SUTURE ZONE IN THE UPPER CRUST OF THE SOUTHERN AND MIDDLE URALS

T5-14 C. Juhlin and C.-H. Wahlgren
HIGH RESOLUTION SEISMIC IMAGING OF DEFORMATION ZONES IN SW SWEDEN

T5-15 F. Masson, C. Prodehl, M. Landes, F. Hauser and B. Jacob
CALEDONIAN AND VARISCAN STRUCTURES IN SOUTHWESTERN IRELAND EXPLORED BY WIDE-ANGLE SEISMIC PROFILING AND TELESEISMIC STUDIES

T5-16 A. Pérez-Estaún, J. Gallart, V. García-Dueñas reporters of the ESCI-Working Groups
ESCI: THE DEEP SEISMIC PROGRAM IN SPAIN. A REVIEW

T5-17 J. A. Pulgar, J. Gallart, G. Fernández-Viejo and D. Pedreira
VARISCAN AND ALPINE SEISMIC SIGNATURES ON THE NORTHERN IBERIAN PENINSULA

T5-18 J. Gallastegui, J.A. Pulgar and J. Gallart
A NORTH-SOUTH CRUSTAL TRANSECT ACROSS THE NORTH IBERIAN MARGIN AND THE CANTABRIAN MOUNTAINS (NW SPAIN)

T5-19 H. Thybo, S. Zhou and E. Perchuc
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Spain

Abstracts

Oral Presentations

ORAL PRESENTATIONS

THEME 1: Active/Passive Margins

8:50

NATURE AND ORIGIN OF CONVERGENT MARGINS WITH A VOLUMINOUS WEDGE-SHAPED ROCK BODY - STILL AN ENIGMA

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Along several plate boundaries, seismic reflection records have imaged a pronounced structural style consisting of three superimposed units overlying actively subducting oceanic crust. The basic structure is a "crustal" wedge characterized by high-amplitude reflections at the top and at the base, covered by a sedimentary apron, fronted often by a commonly small accretionary prism and underlain by a distinct sequence of high amplitude - low frequency reflections about 1 km thick. The thickness of the 20 to 50 km wide margin wedge - also called splinter - increases landward from few hundreds of meters at its seaward front to 6 km and even more. The wedge consists of a high-velocity rock. Although the wedge has not been knowingly sampled in marine enviroment there is in few cases evidence that it is composed largely of accreted ophiolite. In the case of Costa Rica the Nicoya Complex could extend the slope and merge as a tectonically disrupted and serpentinized zone with the sedimentary prism. Although the nature of the wedge-shaped rock bodies known from e.g. the Central America and Guatemala subduction zones, the Southeast Sulu Sea, the Celebcs Sea, the Kuril subduction zone is uncertain, it is permissible to speculate on its origin: One possibility is that it originates from thickened oceanic crustal segments formed during accelerated melt production along a former spreading ridge and displayed by a notably thicker oceanic crust. Our seismic data from "normal" oceanic crust suggest that regional accretion was of more pulsating nature. Regional episodes of high magma supply along e.g. the former mid-Atlantic Ridge displayed in the seismic images by a high-reflective lower crust, increased crustal thickness and regionally even by a near-surface sequence of divergent reflectors dipping toward the former spreading axis. We infer that strongly thickened oceanic crust colliding with a continent is too buoyant to be subducted and is instead accreted to the continent, causing a seaward jump of the subduction zone. This is our favored interpretation; however from current geoscientific data from convergent margins characterized by a voluminous and wedge-shaped rock body interpretations cannot be precluded.

9:20

GALICIA BANK-FLEMISH CAP CONJUGATE MARGINS

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From M0 (118 Ma) to C33 (80 Ma), the pole of rotation of Iberia with respect to Eurasia was near Bordeaux with a scissors-opening type for the Bay of Biscay. The error in the longitudinal position of conjugate margins between Iberia and North America is estimated to a few tens of kilometres. We propose to compare a pair of two-dimensional conjugate margins, the western Galicia margin, cylindrical over more than 70 km and its counterpart, the southern Flemish Cap margin, cylindrical over the same length. This means that a profile perpendicular to the strike of each of these two conjugate segments is representative of each margin whatever is its along strike position. MCS Line 11, collected across the Galicia margin (IAM programme), was interpreted simultaneously with refraction data. The geometry of tilted fault blocks in relation with the presence of a serpentinized peridotite body beneath the thinned continental crust and old oceanic crust has been clearly established. MCS Erable Line 36, collected across the SE Flemish Cap margin (Ifremer-Bedford Institute collaborative programme) also shows the existence of a peridotite body at the continent-ocean transition but the geometry of the margin, without the presence of tilted fault blocks is different. The interpretation of these two conjugate lines brings new significant constraints about the formation of non-volcanic passive margins in relation with the deformation and evolution of the upper mantle.

9:40

A NEW VIEW OF THE GALICIA S REFLECTOR: *ISE-97* RESULTS

D.S. Sawyer(1), C.A. Zelt(1), T. Reston(2), J.A. Austin Jr.(3) and the Science Party of R/V Maurice Ewing Cruise 97-05

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Preliminary analyses of MCS and OBS data from the Iberia Seismic Experiment (ISE-97) suggest that the S-reflector, although definitely a low-angle fault surface, may not have been the single, primary, detachment controlling the rifting which formed the Galicia margin. Rather it appears that S is the last of a series of similar faults that stepped progressively westward and detached progressively thinner slices of extended continental crust. Each of these detachments is bounded to the east by a breakaway fault and to the west forms a structural Moho. Our data confirm that where S is well developed, it does seem to form the crust mantle boundary. The variation of the S-reflector surface also appears more complicated in the along-margin (north to south) direction than heretofore reported. There are a series of faults which begin at the S reflector and dip about 30° to the north penetrating 5-10 km into the upper mantle. In a few places, these faults appear to offset the S reflector in a normal sense. Where the faults intersect S, the reflection character of S often changes. The two later observations suggest that there was mantle involvement in the creation of the S reflector.

10:00

CRUSTAL STRUCTURE OF THE IONIAN MARGIN OF SICILY AND ETNA VOLCANO

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Crustal penetration is achieved on normal-incidence reflection profiles offshore eastern Sicily by using industrial-grade reflection seismics with improved marine sources. The structure of the crust and its thickness show features inherited from the Mesozoic evolution as a passive margin which incorporated Ionian basin crust around the Hyblean continental promontory to the southern plate of the Africa to Europe convergence. They are also markers of the lithospheric deformation due to the late Cenozoic overriding of the northern part of this paleomargin by the Calabro-Peloritan block of European continental crust. This transpressive motion may have been guided along the northern part of this paleomargin where there is evidence of a hinge line between the northward upslope of the Moho of that old passive margin and its downslope to the present slab under the Tyrrhenian sea. Etna is located at the intersection of this mantle upwarp by a zone of active sea-bottom normal-faults which cut across the compressional belt. Updip of the southwestern lateral edge of this slab and in its geometrical prolongation to the SSE of Etna, an active lithospheric fault is imaged which cuts over more than 100 km into the Ionian basin. The onset of Etna volcanic activity is roughly coeval with that of the cessation of interplate thrusting and could hence be related to a change of the coupling of the Ionian slab and mobilization of material at the edge of the subducted slab.

10:20

SEISMIC IMAGES OF THE CONVERGENCE ZONE FROM SOUTH OF CYPRUS TO THE SYRIAN COAST, EASTERN MEDITERRANEAN

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(3) Dept. of Geology, Moscow State Univ., Moscow. Russia Federationn Federation

We present the new results of the processing and interpretation of deep seismic data recorded in the eastern Mediterranean, at the site of the active plate boundary between Europe and Africa. The data required careful processing, including individual deconvolution operators to remove the effects of ghost and bubble, and to improve temporal resolution. Primary reflections were masked by multiple energy from the seafloor and uppermost sedimentary layers, the removal of which required FK and wave-equation demultiple procedures. Pre-stack depth migration provides the first depth images for the area, and these reveal several stages of convergence from W to E. The interpretation of the seismic reflection profiles suggests that the prolongation to the east of the Anatolian-African plate boundary located between south Cyprus and the Eratosthenes Seamount, runs along the junction of the Hecateaus Rise and the Levantine Basin. To the East, it does not constitute a single narrow zone, but rather appears to be distributed along a wide zone of deformation with two major sub-parallel faults at the Latakia and Lanarca ridges. Due to the oblique convergence of the African plate and the westward movement of Anatolian plate, we observe major changes in the geometry of these faults along the lines. The deformation is upper Miocene in age. The abrupt termination of the Levantine basin against the Hecateaus Rise-Latakia Ridge seen in the seismic images suggests the possible strike-slip nature for this boundary. There is no evidence to support subduction and our interpretation infers that lateral movements govern the present tectonism in this area.

11:10

CRUSTAL STRUCTURE AT THE CONTACT BETWEEN THE RIVERA PLATE AND THE JALISCO BLOCK (WEST COAST OF MEXICO)

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The CORTES-P96 deep seismic experiment carried out during spring 1996 aboard the R/V Hespérides, acquired new seismic images that provide good information to outline the structural contact between the Jalisco Block and the Rivera Plate. The data set consist in a succession a MCS profiles from the southern contact between Jalisco Block and the Rivera FZ till the northern termination of the Middle American Trench (MAT). Moreover, 9 OBS displayed along the MCS profiles and 8 landstations located along the coast provide supplementary constraints to determine a consistent model of subduction for the western Mexico. The northern section of the Rivera plate, SW of Bahia Banderas, is well controlled by the coincidence of the MCS and wide-angle seismic profiling. The high quality of the recorded signal allows to identify an accretionary prism of 20 km of extension with P-wave velocity of 3.5 km/s. The overriding oceanic plate subducts with a variable angle from south to north, showing a mean dip angle of 9°. This oceanic plate (Rivera plate) has a mean thickness of 4 km, and is just located beneath a low velocity layer of 3.3 to 3.9 km/s, which seems to be a typical feature of the MAT. The upper mantle velocity measured beneath the subducting plate is 7.8 km/s. At the most Southeast section of the Rivera plate, the structural complexity produced by the conjunction of the east termination of Rivera FZ, the Jalisco Block and the MAT, makes difficult a clear image of the subducting slab. Although, from a careful analysis of the dataset we suggest that the oceanic crust subducting along the MAT is younger that previously though, and might indicate an altered EPR termination. The joint interpretation of the various data set obtained during CORTES-P96 allow to propose a global model of subduction for the Rivera Plate beneath the Jalisco Block.

11:30

DEEP REFLECTION IMAGING AND DRILLING AT CONVERGENT MARGINS PERSIST IN DOCUMENTING SUBDUCTION-CAUSED EROSION OF UPPER PLATE LITHOSPHERE: NEW EXAMPLE FROM COSTA RICA AND THE BROADER IMPLICATIONS FOR INTERPRETING SEISMIC IMAGES OF ANCIENT OROGENIC BELTS ARCS

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(3) Geology, Univ. Firenze. Italy

Full-crustal seismic imaging, and recent coastal studies and ODP drilling of the convergent margin of Costa Rica, which connects the pre-Mesozoic continental crust of the Americas, appear to document rapid rates of subduction erosion during the past 20-25 my (i.e., 2-3 km of landward trench advance/my). Since the late Oligocene, an outboard sector of the margin at least 50-60-km wide has been removed and the material either underplated beneath onshore Costa Rica or recycled to the mantle. Similar results and implications have been reported from four well-imaged segments of the Chile margin (one drilled), and from the Tonga (drilled) and the Scotia (not drilled) subduction zones. By implication, the imaged architecture of the upper plate of an onshore orogenic belt is likely to reveal the seaward-truncated grain of its older or pre-collisional rift or arc fabric. By implication, Proterozoic and Archean continental reconstructions must depend upon success in re-connecting a rock and structural framework abridged (foreshortened) increasingly with time by cycles of subduction erosion, each potentially involving hundreds of km of crustal truncation. The Pacific margin of most of South America is a modern or Meso-Cenozoic example of severe cratonal truncation.

11:50

STRUCTURE OF THE CONTINENTAL CONVERGENT PACIFIC MARGIN OF NICARAGUA

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Three reprocessed multichannel seismic reflection sections across the offshore part of the Pacific Margin of Nicaragua comprise a cross section about 140 km long. The cross section traverses the Sandino Forearc Basin from near the shoreline to the middle continental slope. Seawards, the data show a small accretionary prism at the base of the landward slope of the Middle America Trench and beyond is the rugged topography of the oceanic subducting plate. In addition to standard processing, we obtained depth sections through iterative pre-stack depth migration. The result is an accurate depth section to about 9 km depth. We have mapped the seismic basement and define 6 seismic stratigraphy units in the fill, based on structure of the strata, their seismic character and velocity information. Two wells provide ages of the main seismically defined units. Detail velocity information obtained from focusing analysis can be used as an indicator of possible lithology. The forearc Sandino Basin depocenter is more than 9 km deep near the coast line. It contains sediment from Eocene (or upper Cretaceous?) to recent. A major event in the tectonic history of the basin was uplift of the 30 km wide tract that currently forms the edge of the continental platform. Major uplift was between early Eocene and Oligocene time. In the center of the forearc Sandino Basin folding and faulting display a growth history since pre-Eocene time. The major phase of compression in the forearc basin was during early-middle Miocene, coeval with the collision of the Central and South American plates. Pervasive normal faulting and slight doming of the strata overlying the outer basement high indicates local ongoing uplift. This area is located above the seismogenic zone, where coupling along the plate boundary is strong. This indicate that the uplift and normal faulting are a response of the upper plate to stresses building in the area of coupling. Alternatively, the uplift and normal faulting could be caused by underplating at the base of the upper plate of sediment that bypasses the small frontal prism.

12:10

ANCORP'96: IMAGE OF ACTIVE DEHYDRATION OF THE SUBDUCTING NAZCA PLATE IN THE CENTRAL ANDES

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Two strong reflective zones are imaged at a depths of 20-30 km and 40-80 km in the Central Andean forearc at 21°S as a result of the ANCORP'96 experiment which shows the deepest so far acquired reflections from a subduction zone. The deep reflective zone (Nazca reflector) is dipping sub-parallel to the Wadati-Benioff zone, but is by 20 km above it. The intensity of the Nazca reflector increases downdip with the brightest reflections at the 65-75 km depth range but abruptly dissapears below 80 km. Both, the brightest part of the Nazca reflector and the shallow reflection zone (QB bright spot) are exceptionally bright reflectors with estimated apparent reflectivity coefficients higher than 0.2. Three interpretations of the Nazca reflector are discussed in which it is associated either with an active metamorphic-reaction front in the upper plate mantle, or with friction melting within the shear zone, or with tectonically eroded continental material. These different models could be efficiently distinguished from joint interpretation of P- and S- wave reflections which is however limited because only vertical-component seismic records are available. The preferred model explains both, the Nazca reflector and the QB bright spot as fluid traps located at fronts of recent hydration of the mantle (Nazca reflector) and crust (QB bright spot) the fluids being supplied by the dehydration of the upper layer of the oceanic crust of the subducting Nazca plate. This dehydration is nearly a-seismic. Intermediate earthquakes are associated with dehydration of the lower oceanic crust and the uppermost mantle which contains much less water than the upper crust.

12:30

THE EROSION SUBDUCTION PROCESS OFF NORTH CHILE DERIVED FROM CINCA GEOPHYSICAL AND GEOLOGICAL DATA

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In 1995 a comprehensive set of amhibic geoscientific data was acquired at the active continental margin off North Chile between 18° and 26° southern latitude by German, Chilean and Spanish research institutions: CINCA. Prevailingly on the basis of the marine MCS data in combination with off- and onshore seismic wide-angle/refraction data a model of tectonic subduction erosion could be developed that involves to a great deal gravitational mass transfer and removal from the upside of the continental slope. Tilted and rotated blocks have been identified at different depth levels along the continental wedge. The listric shape of normal faults and deeper reflector units clearly demonstrate an extensional regime deeply transsecting the wedge. High-resolution bathymetric data, wide-spread turbidites and the presence of slumps, strongly indicate gravitational effects and downslope mass transport toward the trench. At the foot of the slope a wedge-like unit of up to 2 km thickness with reduced seismic velocities and basically irregular reflection pattern was detected. We believe that this is the dumping site of all the down-slid rock material that subsequently is filled into the gaps of the oceanic crust that are provided by horst and graben formation on top of the oceanic crust by bending when approaching the trench. The open volume of the gaps is around 40 to 50 km^3 per Ma and per km trench length. Mixed with broken oceanic rocks the debris is taken away in the subduction process similar to a conveyor belt. This implies a transition from the extensional regime of the shallower parts of the slope to a compressional one at its foot and at the subduction plane. About 30% of the eroding continent is assessed to be removed by this process and subducted with the downgoing slab.

15:00

THE CRUSTAL STRUCTURE OF A PASSIVE MARGIN: A TRANSECT ACROSS THE AUSTRALIAN NORTH WEST SHELF

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Ocean bottom and land seismometers were deployed along a 720 km transect extending from the onshore Kimberley to the Argo Abyssal Plain. The refraction traverse is coincident with deep reflection seismic lines recorded to 16 seconds two-way-time. This, coupled with gravity data, was modelled to provide a section 950 km long and 70 km in depth. A major transition from an average crust to a highly thinned crust occurs geographically at the transition between the Proterozoic shelf and the main Mesozoic Basin. The crust thins rapidly over 50 km section from 37 - 25 km with the Moho bowing upwards. The area of thinning is coincident with upper crustal discontinuities; block faulting extends from the Mesozoic Basins into the lower crust and reactivation is demonstrated. Velocities of 5.8 - 6.0 km/s in the upper crust are probably reflecting granite composition. A pod at the base of the crust, inmediately eastwards of the discontinuities, is anomalously thick and has a velocity of 7.0 km/s which may be indicative of underplating. Paleozoic tectonic events shaped the container for Phanerozoic deposition as established from the westward thinnig of the margin during the Mesozoic depocentres. The lower crust may have undergone brittle deformation as demonstrated by presence of possible shear planes interpreted on seismic. A deepening of the simple to pure shear transition zone may be a characteristic of passive margins.

15:20

INELASTIC BEHAVIOR OF THE LITHOSPHERE AND ITS CONTROL ON FORELAND BASIN DEVELOPMENT: NORTH WEST SHELF OF AUSTRALIA, TIMOR SEA.

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The Timor Trough is a modern 'underfilled' foreland basin created by partial subduction of the outer north west continental shelf of Australia beneath Timor Island in the Outer Banda Arc of eastern Indonesia during the Cenozoic. A change of the effective elastic thickness (EET) of the continental foreland lithosphere from ~80 ±20 km to ~25 km over a distance of ~300 km explains (1) the high curvature ($\sim 10^{-7}$ /m) on the outer Trough wall, (2) the low shelf forebulge (~200 m) as measured along a reference base Pliocene unconformity, and (3) observed gravity. An inelastically yielding quartzite-quartz-diorite-dunite continental rheology can explain the EET gradient. New, shallow crustal (<8 km), seismic reflection images indicate that Jurassic basement normal faults are reactivated during bending of the foreland.

15:40

CRUSTAL STRUCTURES OF THE PHILIPPINE SEA PLATE NEAR TAIWAN ARC-CONTINENT COLLISION ZONE

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The complicated western boundary of the Philippine Sea plate is defined from north to south by the northwestward subduction along the Ryukyu arc-trench system, arc-continent collision on Taiwan, and eastward subduction of the Eurasian plate along the Luzon arc-trench system. High rates of seismicity observed in eastern Taiwan and its offshore region clearly indicate that the western corner of the Philippine Sea plate near Taiwan is undergoing active deformation. Results from recent multichannel seismic reflection surveys and the TAICRUST deep seismic imaging survey have provided new insights into the crustal structures and deformation along the plate boundary of this arc-continent collision zone. Wide-angle reflection/refraction data recorded by ocean bottom seismometers (OBS) east of Taiwan and onland instruments deployed across the Coastal and Central Ranges on Taiwan, suggest an abnormally thick oceanic crust (about 15 km in thickness) underlain the Huatung Basin east of Taiwan. Crustal thickness increases rapidly to the west starting from the eastern flank of the Luzon Arc and reaches 50 km under the Coastal Range, indicating thickening of the Philippine Sea plate due to arc-continent collision processes. Seismic reflection profiles in the Huatung Basin show thick (1 to 3 s TWT) sedimentary strata lying on top of oceanic crust. Beneath these strata, the basement surface exhibits large-scale relief and is underlain by mid- and lower crustal reflections, all of which may reflect deformation of the oceanic crust. However, the overlying sediments are little deformed. A prominent unconformity is observed in the northern Huatung Basin that acts as a basal detachment for the upper sedimentary layer showing gravity-sliding structures. Folds and east-verging thrusts are observed only along the eastern flank of the Luzon Arc. From the velocity model and seismic reflection images, crustal thickening appears to be concentrated within the Luzon Arc, or in the lower part of the oceanic crust along the western edge of the Philippine Sea plate, and crustal deformation of the Huatung Basin basement imaged on the seismic reflection profiles occurred either before or in the early stage of the arc-continent collision, leaving the overlying post-collisional sediments little affected.

16:30

CRUSTAL STRUCTURE OF THE NORTHERN TIP OF THE ANTARCTIC PENINSULA FROM WIDE-ANGLE AND NORMAL INCIDENCE SEISMIC DATA

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The Hero FZ intercepts nearly orthogonal the Pacific margin of the Antarctic Peninsula (AP) at about 63° S; it separates a progressively older and older passive margin, to the SW, from an active subduction with associated back-arc extension (Bransfield Strait) to the NE. During the austral summer 1996-97, a joint Italy-Argentina geophysical study (TENAP project) was carried out across the northern tip of the AP, on either sides of the Hero FZ, to reconstruct the crustal structure and the deformation processes in the area. The measurements undertaken include active source and passive seismology, gravity, total magnetic field and geology investigations. Three near vertical reflection seismic profiles (about 700 km in total) were acquired on the Pacific side of the AP, using a 3 km long multichannel streamer and a 60.5 litres air gun array, operated in "single bubble" mode, shooting every 50 m. A second passage was performed along the same lines, shooting into OBS and land stations only, with a 250 m interval. The energy was recorded by digital ocean-bottom seismographs deployed in 16 positions along the lines and by 15 portable seismic stations deployed on the AP, up to a source-receiver distance of 240 km. Preliminary models from the active source seismic measurements indicate a crustal thickness of about 40 km for the AP cordillera and a crustal structure of its pacific margin differing significantly across the Hero FZ: a back-stop characterised by rifting, block faulting and Moho depths of 16-18 km beneath Bransfield St., to the NE, contrasts with a passive margin where the Moho depth is about 25 km, to the SW.

16:50

BASIN DEVELOPMENT ALONG THE SCOTIA/ANTARCTICA PLATE BOUNDARY (NORTHERN WEDDELL SEA)

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The Scotia/Antarctic plate boundary at the NE end of the Antarctic Peninsula is characterised by transcurrent fault zones with oblique slip kinematics deforming elements of continental crust. The crustal blocks are bounded by the oceanic crust of the Scotia and Antarctic plates and result from major processes of continental fragmentation and sea floor spreading that affected the Antarctic Peninsula during the Cenozoic. The northern Weddell and Scotia seas contains the following principal morphostructural elements: (1) the South Scotia Ridge and the South Orkney Microcontinent, both with continental crust; (2) the oceanic Powell and Jane basins; and (3) Jane Bank, which belongs to an island arc. The analysis of MCS profiles and of gravimetric and magnetic data from Russian, Italian and Spanish cruises, supplemented with satellite gravimetric data, has enabled us to determine the relationship between these elements and to propose a model for the main stages of Cenozoic evolution in the area. During the early Cenozoic, the Weddell Sea oceanic crust was subducted under the southern margin of the South Orkney Microcontinent. The subduction probably ended westwards at the South Powell Ridge, a submarine extension of the Antarctic Peninsula. A major transcurrent fault zone is identified in the northwestern Weddell Sea, bounding oceanic crust of Mesozoic and Cenozoic ages. This fault zone was probably active at least to the Miocene. The drifting of the South Orkney Microcontinent from the Antarctic Peninsula during the late Eocene to early Miocene originated the Powell Basin. Jane Basin developed as a backarc, related to the subduction of the Weddell Sea oceanic crust below Jane Bank. The seismic stratigraphy of the depositional sequences in these two basins indicates that spreading in Jane Basin started simultaneously with the end of the opening in Powell Basin. The active spreading ridge of the Weddell Sea collided with the trench and was subducted below Jane Bank at 15-20 Ma. Drifting in Jane Basin and subduction below Jane Bank ended shortly thereafter, in the middle Miocene, and the boundary between the Antarctic/Scotia plates migrated north of the South Orkney Microcontinent, along the South Scotia Ridge. Present tectonic activity in the region is minor.

17:10

DEEP SEISMIC IMAGING OF THE NANKAI TROUGH SEISMOGENIC ZONE FROM MULTICHANNEL AND OCEAN-BOTTOM SEISMIC DATA

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The Nankai trough, southwestern Japan, is recognized as a vigorous seismogenic zone with well studied subduction earthquakes. The plate coupling of this zone seems near 100 percent as the plate motion is fully accommodated by M8-class interplate events. In 1997, we performed multichannel seismic (MCS) reflection study and Ocean-bottom seismograph (OBS) active study around the western Nankai trough across a co-seismic slip zone of the 1946 Nankaido earthquake (Ms=8). The MCS-OBS data were acquired along three dip (50 - 250 km) and strike (120 km) profiles, and a total of 25 OBSs and one land station were deployed. The main purpose of our seismic study is to image the subducting oceanic crust and overlaying forarc crust down to 30 km, which we suppose to be a seismogenic zone of the 1946 earthquake. It is, especially, the most important target to examine the spatial relationship between the area of the co-seismic slip zone and the structure we obtained. The MCS data show a clear thrust fault cutting through the accretionary sediments. The OBS wide-angle data also strongly indicate that the boundary between the accretionary sediment and the forearc crust is located 20 - 50 km landward of the oceanward edge of the co-seismic slip zone.

17:30

MARINE SEISMIC PROFILING ACROSS THE BEPPU BAY, NORTHEASTERN EXTREME OF THE BEPPU-SHIMABARA GRABEN, SOUTHWEST JAPAN

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The Beppu-Shimabara Graben running across Kyushu island constitutes a very rare example in the Japanese islands of active extensional tectonics with both high volcanism and active seismicity. Futhermore, the graben is located in a geologically complex region, and its origin and history are still controversial. Moreover, thick pyroclastics filling the graben have made it difficult to resolve the controversies. Therefore we conducted a marine seismic profiling project across Beppu Bay, the northeastern extreme of the graben. The results indicate: (1) The southern border of the graben is formed by a gently N-dipping listric fault, which becomes subhorizontal at about 5 km deep. In contrast, a distinct northern border does not exist. (2) The hanging wall has been moving in a normal sense with a right-lateral component. (3) A distinct reflector at 8 km depth may correspond to the top of a magma chamber beneath the graben. These observations provide important new constraints on the tectonic problems related to the graben.

8:30

COSEISMIC AND INTRASEISMIC STRAIN ACROSS THE KODIAK MARGIN, ALASKA

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A seismic reflection line from the Aleutian Arc across the Kodiak shelf to the Alaska Trench was pre-stack depth migrated and further constrained with wide-angle OBH (Ocean Bottom Hydrophone) seismic velocity data and swath mapping. The seismic reflection image quality allowed interpretation of individual thrust slices, the back stop, and structure to the base of the upper plate and balancing of the section. Tectonic shortening during the past 3 Ma and age data provided rates of permanent contraction over five discrete segments from the trench to the landward flank of the forearc basin. Between 60% and 70% of the plate convergence is measured as contraction across the 50-km-wide accretionary prism which comprises less than 15% of the forearc. Permanent contraction is minimal across the aftershock zone of the 1964 Alaska earthquake above the Kodiak rupture zone. Elastic strain was approximated from the historical record of the 1964 Alaska earthquake. The 1964 coseismic vertical deformation displays an inverse pattern to the permanent strain consistent with the earthquake cycle concept. Elastic deformation is dominant beneath the shelf and upper slope, rapid permanent deformation is concentrated beneath the lower slope, and a transition between them occurs beneath the middle slope.

8:50

DELAMINATION-WEDGE STRUCTURE BENEATH THE HIDAKA ARC-ARC COLLISION ZONE, CENTRAL HOKKAIDO, JAPAN

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The Kuril Island Arc (KA) has been colliding against the Northeast Japanese Island Arc (JA) since Middle Miocene, forming the Hidaka Collision Zone (HCZ) at the western front of KA in central Hokkaido. Recent seismic reflection surveys across the HCZ have revealed new aspects of deep structure including: (1)Lower crustal laminations are clearly observed beneath the KA. (2)The zone of lower crustal lamination is divided at about 7 s into upper and the lower. (3)The upper half has been thrust westward over the JA, whereas the lower half continues downward. This means that the lower crust of KA is delaminated at about 7 s. (4)A wedge of JA intrudes between the delaminated lower crust of the KA. (5)Earthquakes occur mainly in the wedge of JA. This delamination-wedge structure provides essential information on the colliding and merging process between the two arcs.

9:10

DEEP TO SHALLOW SEISMIC REFLECTION PROFILING ACROSS THE ACTIVE SENYA FAULT, NORTHERN HONSHU, JAPAN

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The Senya fault is a typical active thrust in northern Honshu Japan and generated the 1896 Riku-u Earthquake (M7.2). The deep and shallow seismic reflection profiling across the Senya fault, was undertaken to reveal the continuous geometry from deep seismogenic fault to shallow active fault. Along the 25-km-long seismic line, deep seismic profiling was performed using four Vibroseis trucks and 30-500 kg dynamite at about 5 km intervals. High resolution shallow seismic reflection profiling also revealed the frontal structure of the Senya fault. Both result provides the detailed structure of the Senya fault in the upper crust. The probable extension of Senya fault merges to a horizontal mid-crustal detachment at depth of 12-15 km, and shows listric geometry dipping from 30-50 degrees in the upper crust. At depth of 1 km, it has a detachment again in Tertiary mudstone and becomes emergent thrust dipping 30 degrees. In Northern Honshu, thin-skinned tectonics is applicable for the deformation of late-Tertiary sedimentary rocks. Low angle detachment fault commonly accommodates in the Miocene mudstone deposited post back-arc opening stage. Deep seismogenic fault shows relatively simple geometry in the upper crust and strongly controlled by inversion tectonics; Miocene normal fault reactivated as reverse fault.

9:30

INTEGRATED SEISMIC PROFILING ACROSS THE NORTHEASTERN HONSHU ARC, JAPAN

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To understand the mechanism of earthquake occurrence in intra-island-arc crust with its deformation process, we are conducting an integrated seismic experiment across the northeastern part of Honshu arc at about 40° N, Japan, since October 1997, including both passive and active sources. The target of the experiment is to image the whole crustal section with a special attention to deep structure of active faults. We have deployed 50 temporary 3-component seismic stations from which data are transmitted through a satellite communication system. The active experiment includes a 150-km long refraction profiling on land and 220-km in the Japan Sea. A 30 km-long reflection survey was also carried out in the central part of the Tohoku arc. The study is still undergoing to accumulate seismicity data till next spring. The preliminary results indicate that an active fault continues to a detachment fault at a depth of about 15 km in the island-arc crust.

THEME 2: Integrated multidisciplinary studies

10:00

REFLECTIVITY AND VELOCITY AT KOLA AND KTB SUPERDEEP BOREHOLES

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The Kola borehole in NW Russia and the KTB borehole in Germany penetrate crystalline rocks to depth of 12.4 and 9.1 km, respectively, and provide a new understanding (calibration) of seismic crustal reflection data. A major result of deep scientific drilling is that both boreholes produce brines down to their TD. The Kola borehole penetrates 7 km of compositionally variable Proterozoic meta-volcanic and meta-sedimentary rocks and 5 km of Archean gneisses and amphibolites which dip between 30 to 50°. The Proterozoic sequence is highly reflective. Reflectivity is produced by compositional boundaries, shear zones, anisotropy and fluid-filled fractures as indicated by lower seismic velocities. Horizontal reflections that cross the general dip are attributed to fluid-filled fractures. The KTB borehole penetrates near vertical layered gneisses and amphibolites. Here, in contrast, reflectivity is primarily caused by fluid-filled fractures in brittle fault zones such as a steeply dipping fault intersected at 7 km depth. The seismic signature of this zone is highly variable on a scale smaller than a Fresnel zone indicating that both surface seismic and logging results are necessary to understand the nature of crustal reflectors. Several kilometers below TD is the unusually strong horizontal Erbendorf reflection. Seismic velocities in both boreholes are lower than intrinsic rock velocities; this phenenom is attributed to the general presence of fluid-filled voids, supplying the brines that flowed into the boreholes. Thus seismic estimates of crustal composition are biased toward values that are too felsic.

11:00

REFLECTION, REFRACTION AND EARTHQUAKE TOMOGRAPHY: EXAMPLES FROM ETNA VOLCANO AND GREEK SEISMOGENIC ZONES

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Crustal composition and evolution has been largely approached with so-called refraction seismics able to describe gross layering between interfaces. Normal-incidence reflection seismics extended at crustal scale has brought the spatial resolution allowing new important insights of its own, for instance on the fabric and deformation and internal fine structure. Accordingly crustal seismic surveys are now generally aiming at combining reflection and refraction data in coincident 2D sections. The 3D nature of geological objects is instead central to tomographic approaches, but such studies generally map deviations of transmission velocity with a crude spatial resolution. Though, from local earthquakes they may provide reasonably fine resolution as well as S information. For those structural heterogeneities for which understanding at lithospheric scale is required, teleseismic arrival time tomography allows to describe also the mantle part, although refraction and reflection seismics have proved successful in several instances to provide original views of elements of mantle structure, which are not yet well integrated in more current low-resolution representations. Integrated surveys, e.g. in Tibet or the Andes, have shown that not only architecture but composition or physical state could be studied in some cases in detail from S waves in addition to P, and illustrate the power of adding still other seismological methods like receiver function and anisotropy analyses, and surface wave dispersion for a more complete image. On specific targets for which the structural heterogeneity at diverse scales is of interest, the combination of the different approaches mentioned, with artificial as well as natural seismics offers now the opportunity of sufficiently different sampling geometries and resolution scales. This allows to tackle now the problem of the relation of structural heterogeneity with volcano evolution and seismogenesis, with a bearing on natural hazards. Examples from the Ionian and Aegean domains are presented.

11:30

SEISMIC TRAVEL TIME TOMOGRAPHY STUDIES OF TWO VOLCANOES, THE LONG VALLEY CALDERA, CALIFORNIA, AND THE HENGILL VOLCANO, ICELAND

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The Long Valley caldera, located on the edge of the Sierra Nevada in east central California, is one of the largest active rhyolitic volcanic systems in the world. Situated in a completely different environment, the mid-Atlantic Ridge in southwest Iceland, is the Hengill central volcano. In both regions the P- and S-wave velocity structure has been examined to depths of 12 km below sea level, using travel times from local earthquake and controlled source data. Despite the vast difference between the study regions, the resulting velocity models have some common features. Neither of the volcanoes show any pronounced simply-connected low-velocity S-wave bodies. Instead, reduced P-wave velocities control the top 12 km of the crust beneath the centers of eruption. Though volcanically active in the last few thousand years, this indicates that neither of the volcanos have a large discrete magma chamber. The low P-wave velocities instead indicate hydrothermal activity and the presence of supercritical fluids deep in the crust.

11:50

WHAT ARE CRUSTAL SEISMIC SURVEYS TELLING US?

G. F. West

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Seismic reflection and refraction surveys of continental crustal structure have now been widely carried out for more than 15 years. Nevertheless, much controversy remains about what aspects of crustal geology are being imaged and just what all this seismic effort is teaching us about crustal geological processes. In this paper, I put forward my observations and conclusions for discussion. Briefly summarized, a case can be made that the seismically imaged base of the crust is a fairly late feature in any orogenic development. The implication is that, in the final stages of orogeny, ultrametamorphism can convert some lower crustal rocks to material with mantle properties. This reconstructs the M discontinuity, flattens out the previous structure and returns the crustal thickness to the standard 35-45 km values. It can also be argued that much of the reflectivity seen in deeper parts of the crust is related to losenge-style brittle-ductile deformation structures in which extensive layers of intense shear strain surround relatively little strained blocks. It appears that this style of deformation is common in lower crustal but not in mantle petrologies. It may also be restricted to certain tempeature- pressure- interstitial fluid regimes. Furthermore, metamorphic processes may be able to obliterate the elastic property contrasts that make these zones reflective. If so, it has an impact on how reflection patterns in the crust should be interpreted. They likely to record the closing phases of deformation in the crust but give no information about associated mantle deformation. They are unlikely to track early phases of orogenic deformation.

12:10

CRUSTAL REWORKING DURING OROGENY: AN ACTIVE-SYSTEM HIMALAYAN PERSPECTIVE

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The Nanga Parbat-Haramosh Massif lies on the western end of the Himalayan Mountain chain in NE Pakistan. This >8 km high peak, sculpted from Indian crust, is the site of rapid uplift, denudation, and young (<1 Ma) igneous and metamorphic activity. Substantial reworking of the crust occurs today as igneous or metamorphic signatures of the original Himalyan collision are absent. Results from an ongoing multidisciplinary study suggest a model of strain induced metamorphism that is supported by geophysical (earthquake source characterization/tomography, magnetotellurics), geochronologic (cooling ages, cooling histories), and petrologic (stable-isotopes, fluid inclusions) data integrated into a geodynamic model. In the model, rapid and dramatic exhumation leads to metamorphism as high-temperature lower-crustal rocks pass through a high-strain zone at depth where volatiles are released. Rocks having passed through the high-strain zone are dehydrated explaining the existence of resistive crust beneath the massif. Rapid decompression generates granitic melts and migmatites. As material is brought to the surface advection of isotherms elevates the position of the brittle/ductile transition. As dry gneisses then pass into the lower strain zone beneath the summit, they are brought into communication with surface waters. Fluids may be released due to shear failure at elevated fluid pressure or due to local hydrofracturing providing the source of some of the microseismicity recorded at Nanga Parbat.

12:30

SEISMIC EXPLORATION OF A CONTINENTAL TRANSPRESSIONAL PLATE BOUNDARY: THE SOUTH ISLAND OF NEW ZEALAND

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During austral summers 95-96 and 97-98 a joint US - NZ programme of multichannel seismic reflection, onshore - offshore wide-angle reflection and seismic refraction was used to study continental deformation in the South Island of New Zealand. Parallel studies of magnetotellurics, passive seismology, P-wave delay and petrophysics also took place in the same field seasons. Principal findings so far include: (1) A rapid asymmetric thickening of the crust beneath and just east of the Indo-Australian/Pacific plate boundary (the Alpine Fault). At the west coast of the South Island (I-A plate) the crust is about 27 km thick yet by 40 km in land it is a maximum of ~46 km. (2)The plate boundary can be traced to a depth of approx. 30 km as an eastward-dipping (approx. 40°) Alpine Fault Zone (AFZ) that is 10-15km thick. (3) The AFZ is seismically quiet, has low seismic velocities (at least for rays passing at right angles through it) and below 20 km has resistivities as low as 30 ohm/m. (4) Teleseismic P-wave delays recorded across the South Island suggest subjacent high velocities in the mantle and a small but distinct low-velocity region in the AFZ. This experiment has underscored the effectiveness of studying the deep crust and upper mantle structure of continental islands, like New Zealand, with the onshore-offshore techniques as a complement to the standard marine and terrestrial seismic methods.

THEME 3:Imaging 2D and 3D heterogeneities and anisotropy

15:00

THE STOCHASTIC CRUST AND ITS SEISMIC RESPONSE

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Geologically and petrophysically the crystalline crust is heterogeneous at all scales relevant to crustal seismic exploration. The complexity of geologic exposures is matched by the complexity of crustal reflection data. The range of scales in crustal structure suggests that the seismic reflection image is a band limited representation of the broader bandwidth heterogeneity spectrum of the crust. We relate the crustal heterogeneity spectrum to the seismic reflection spectrum using a statistical approach, and using the crustal exposures as constraints for seismic models. Statististical analysis of many geologic maps of crystalline exposures shows that they are self-affine, with the 2-D autocorrelation function describing the 2-D spatial fabric. For seismic wave propagation, the other important statistical measure is the seismic velocity probability density function. Over the set of maps that we have examined, the pdfs show considerable variation from binary (two distinct velocities), to quasi-Gaussian (normal continuous velocity variation). Seismic response is a predictable result of the scale parameters of the fabric function, the velocity pdf, and the acquisition parameters. Measurement of the statistical parameters allows us to classify the crust according to wave propagation regime, and to assess the use of different common seismic imaging methods. The statistical model allows us to pose the inverse problem to estimate the stochastic parameters from seismic data. At present we can estimate the fractal dimension and the lateral scale parameter directly from migrated or unmigrated CMP sections, but not the vertical scale parameter due to the typically limited seismic bandwidth and being unable to truly isolate the seismic wavelet.

15:30

STATISTICAL APPROACHES TO INTERPRETING DEEP SEISMIC DATA

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The complexity of the reflection wave fields observed in the crystalline crust has stimulated efforts to use statistical descriptions of the wave field to determine the spatial statistics of the associated geology. These efforts are based on theoretical and experimental work that demonstrate that the spatial statistics of the acoustic impedance fields associated with typical crustal geology and the spatial statistics of the associated reflection wave fields are correlated. The details of the correlation depend upon the dominant mode of seismic scattering. In this presentation we use synthetic and real seismic data to explore some results and limitations of using statistical parameters to derive geological models. In particular, we focus on the combined use of both quantitative and qualitative information such as lateral correlation length, fractal dimension and total power to map variations in the spatial characteristics of the wave field. Qualitative insight into how variations in the statistical parameters are related to variations in seismic wave field characteristics provides a link between standard and statistical approaches to interpretation. Quantitative information forms the basis for construction of geological models that are richer in information content and provide better links between the seismic section and outcrop/map geology.

15:50

THE IMPORTANCE OF MULTIPLE SCATTERING IN 1D BIMODAL FRACTAL MEDIA: IMPLICATIONS FOR IMAGING THE CONTINENTAL LOWER CRUST

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The role of multiple scattering in the lower crust has recently attracted considerable attention in the context of inverting deep seismic reflection data for the crustal structure. Several authors have used indirect methods to estimate its importance. In this study we use the propagator-matrix formalism to directly quantify multiple scattering for 1D bimodal fractal models. By using this formalism we can separate the single and multiply scattered wave-fields. To verify whether a single scattering assumption is justified, we compare the seismic response with and without multiple scattering. Assuming Birch's law to relate density to acoustic velocity, we show that for bimodal (fractal) media in lower crustal conditions the intrinsic strength of the scatterers is determined by the standard deviation (σ_c) of the velocity distribution alone, and depends only weakly on the average velocity. The importance of multiple scattering is studied by varying the strength (σ_c), the size of the scatterers relative to the dominant wavelength of the seismic pulse (ka), and their density. Since the effect of multiple-scattering in 2D/3D would only diminish relative to the 1D-case due to extra geometrical spreading effects, and since many authors have hinted at a fractal bimodal character of the lower crust, this study can be used as a benchmark on the importance of multiple scattering in the lower crust if one can estimate the auto-correlation length (a) and σ_c.

16:40

A TECTONIC MANTLE SHEAR ZONE IN THE SOUTHEASTERN NORTH SEA INTERPRETED FROM MONA LISA DEEP SEISMIC DATA

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Deep seismic reflection and refraction data of the MONA LISA project identify a mantle structure in the southeastern North Sea. The four normal-incidence reflection profiles reveal a southward to westward dipping zone of reflectors from Moho to c. 22 s twt. A layer of very high seismic velocity (>8.6 km/s) and a thickness of 5 km, roughly coincides with the reflective zone along profile 2. Wide-angle reflections indicate the presence of such a layer along the other profiles, but the velocity is unconstrained and must be smaller than along profile 2, because no first arrival refractions are observed. Hence, there is indication of strong anisotropy in the layer, which is consistent with "frozen-in" alignment of olivine crystals. We interpret the layer zone as a tectonic mantle shear zone, which may originate from the late phases of Caledonian collision or post-orogenic collapse and, possibly reactivated, from Late Carboniferous to Early Permian basin formation in the area.

17:00

FAST FULL-ELASTIC 3-D MODELLING OF COMPLEX GEOLOGICAL STRUCTURES

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Full wavefield modelling of complex media on a lithospheric scale has been limited to 2-D because of the enormous computing power needed to run the 3-D finite-difference algorithm. Hybrid-methods offer a solution for areas that have a single complex zone beneath a homogeneous overburden, e.g. oceanic crust in deep water, but even these methods need a seriously big computer to handle a sensibly sized model with efficient boundary conditions over a frequency range used for reflection seismology. The complex-elastic phase screen algorithm may offer a viable solution to the problem. This method implicitly concentrates computer effort at the zones of most complexity, can handle many such zones separated by more homogeneous zones, does not suffer from dispersion, and can be run on a modest sized parallel computer with limited memory. The problems with the algorithm are that it limits scattering to close to the principle direction of propagation, i.e. it is only useful for simulating reflection seismic data, and it does not implicitly handle free-surface or peg-leg multiples. Given these restrictions, the code runs up to 100 times faster compared to 3-D finite difference. Some of the potential uses of the algorithm are to test the effect of 3-D scattering on 2-D profiles, planning 3-D acquisition, and testing 2-D and 3-D processing strategies.

17:20

SENSITIVITY OF THE SEISMIC WIDE ANGLE WAVE FIELD AND FIRST ARRIVAL TIMES TO FINE SCALE CRUSTAL STRUCTURE

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Synthetic seismic viscoelastic wave fields with a dominant frequency of 10 Hz were computed for a suite of progressively filtered crustal models. We use a conventional bimodal self-similar structure superposed on a linear vertical velocity gradient as a synthetic crustal model. Moho is represented as a first order discontinuity with a self-similar depth profile. We compare the sensitivity of the full wave field versus the sensitivity of arrival time picks to crustal velocity structure at different length scales. It is well known that vertical reflection data resolve layers as thin as a quarter of a wavelength. On the other hand we find that the full wave field around Pn is sensitive to crustal wavelengths down to 1 km, and wavelengths on the Moho down to 5 km. The Pn first arrival time picks are sensitive to crustal wavelengths down to about 3 km, and wavelengths on the Moho down to about 10 km, which compares well with the size of the Fresnel zone. Thus, the wide angle wave field has a sensitivity that is intermediate between the sensitivity of vertically reflected wavefield and wide angle travel time picks. These findings give some justification to the mainstream ray tracing approach to wide angle data inversion, where resulting models incorporate only a moderate number of features at relatively large scales.

17:40

FOCUSSING PROBLEMS IN REFLECTION IMAGING OF THE CRUST

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Most crustal reflection surveys are high fold 2D crooked line profiles, and the reflectivity image is produced by some variant of common mid-point stacking. With typical recording parameters, the image should be highly sensitive to the required velocity model, at least in the upper crust. However, sharp focussing is rarely observed, and similar stacks can often be obtained over a wide range of velocities. Peaks in semblance may be observed for some reflections, but even though the events are strong enough to be visible on raw shot-gathers, maximum values are low and only part of the reflection signal survives into the stacked section. Among other consequences, this means that amplitude and waveform studies on reflections may be faulty. We find that losses can be ameliorated by a mixture of improved correction of any time anomalies and more tolerant methods of combining trace signals. The philosophy is to stack data progressively from smaller to larger aperture, first using phase coherent stacking over limited offset ranges, followed by correction of time anomalies due to in-line and cross-line dip, and eventually using (if necessary) phase-insensitive amplitude stacking to include full aperture data. Tests have also been made of phase incoherence caused by complex reflector geometry. Examples of the problems and suggested remedies are given.

THEME 4: Intra-continental collisions

8:30

COLLISIONS, CONTINENTS AND REFLECTIONS FROM THE LITHOSPHERE

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For more than 20 years deep reflection profiling has provided a framework for delineating structures of the continental crust and lithosphere. Few profiles, however, have mappable reflections from the lithospheric mantle. Where they do, mantle boundaries are often interpreted as relict subduction zones, although relating them to surface subduction scars has been difficult. New LITHOPROBE data from the Precambrian Shield in northwestern Canada provide images of nearly continuous mantle reflections that are followed from about 100 km depth, where they are situated beneath a ca. 1.9 GA magmatic arc, into the crust, where they are correlated with coeval regional convergent structures. These results affirm that deformation of the lithosphere is analogous to that of a layered medium, with detachments occurring at transitions in rheological properties. The crust-mantle transition is a prominent detachment due to the large contrast in rheology across it, and there is increasing evidence from subcrustal reflections that the lower lithosphere deforms by thrust imbrication. Continental growth thus takes place in three ways: (1) lateral expansion, as terranes, arcs, and continental fragments are accreted to the margin of a craton; (2) tectonic delamination, as buoyant crustal rocks are detached from the lithosphere below and thrust over the continent above; and (3) subcrustal imbrication, as subducted lithosphere is repeated by thrusting. Tectonic delamination occurs at all scales in orogens, and subcrustal imbrication may be imaged for the first time on the new LITHOPROBE profile. According to these results, accretion takes place below the crust at the same time that outward growth of a craton occurs at the surface when lithospheres merge.

9:00

MULTIPLE EPISODES OF CRUSTAL DEFORMATION IN A BROAD ZONE SPANNING THE BOUNDARY BETWEEN THE SHIELD AND YOUNGER TERRANES IN SE AUSTRALIA.

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The Tasman Line is the boundary between the Proterozoic shield in central and western Australia and the younger Phanerozoic Belts in the east. SE of the Broken Hill Block, it has been interpreted as a transform margin during the break up of Rodinia, and is defined by NE-SW trending gravity and magnetic anomalies and a topographic feature defining the course of the Darling River. None of these is coincident. A seismic reflection and refraction transect revealed that the Broken Hill Block in the NW of the transect comprises several blocks separated by a 25-30 km wide deformation zone, in which SE dipping, apparently planar shear zones penetrate to middle to lower crustal levels. The shear zones are believed to be Proterozoic in age but topography across them implies recent movements. Predominantly SE dipping shear zones are also intepreted SE of the deformation zone. Some link into sub-horizontal detachment surfaces at 10-20 km depth, but others farther to the SE truncate against strong, NW dipping reflections in the middle to lower crust beneath the Phanerozoic terranes. They define a triangular shaped region in the crust at least 80 km wide which underpins the boundary between the shield and younger terranes. The upper crust in this region is largely unreflective, and is thickened in places, presumably by thrusting. The age of the presumed thrusting is indicated by deformation in sediment cover to be post Middle Devonian. The shear zones within the crust, including those which penetrate the whole crust and those clearly limited to the upper crust, form conjugate sets. The boundary between the shield and the younger terranes is therefore not a "line" but rather a broad deformation zone in which old structures in the NW continued to be active as younger deformation occurred to the SE.

9:20

CRUSTAL STRUCTURE ACROSS THE COAST MOUNTAINS, SE ALASKA

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Crustal and uppermost mantle structure along the 250-km long ACCRETE line across the Coast Mountains, SE Alaska, is analyzed using a combination of several travel-time analysis methods and pre-stack migration of wide-angle seismic data. Additional constraints on the model are obtained from correlation with a vertical-incidence multichannel seismic section. Inversion of the PmP and crustal reflection travel times results in a detailed velocity structure with moderately high crustal velocities, low velocity gradient in the middle crust, and decreasing average crustal velocity and a deepening Moho towards the NE. The model reveals a change of reflectivity across the region of the Coast Shear Zone (CSZ). To the west of the CSZ, several groups of mid- to lower crustal reflectors probably correspond to the mid-Cretaceous thrust system mapped on the surface. Beneath this system, a sharp variation in Moho may indicate a former subduction zone. A reflector dipping SW nearly to the Moho constrains the NE flank of the Coast Mountains batholith (CMB). NE dipping fabric associated with a ductile top to the east or NE deformation is identified within the top of the CMB. A localized body above the Moho probably corresponds to the S-wave "bright spot" observed before. Variations of crustal velocity structure, the character of reflectivity, and Moho topography correlate with the boundaries of imaged tectonic structures.

9:40

REFLECTIONS ON ASSEMBLY OF WESTERN LAURENTIA: THE ROLE OF TECTONIC BOUNDARY CONDITIONS

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Laurentia, the cratonic nucleus of North America, is a mosaic of crustal domains that amalgamated through multicollisional assembly, primarily in the interval 2.00 - 1.78 Ga. During this period, tectonic boundary conditions (e.g., tectonic escape vs. entrapment) exerted first-order controls on plate convergence, thermal structure and orogenic style. These attributes are expressed in observed reflection fabrics on Lithoprobe seismic profiles, potential-field patterns, and in the distribution and orientation of conductive domains in the lithosphere. Tectonic escape at the leading edge of the Slave indenter was accommodated by accretion south of the Great Slave Lake transform, geometrically analogous to the modern Indo-Eurasian collision. Accretion of tracts of Proterozoic crust south of the transform was accommodated by a complex series of collapsed marginal basins and subduction systems. The southern boundary of this accretionary system was a marginal basin within the Snowbird Tectonic Zone, which acted as a tectonic free-face. Eventual closure of the free face, an essential element of tectonic escape, led to development of a stress field conducive for emplacement of mid-crustal sills over large parts of western Canada. Tectonic confinement of the Archean Hearne Province, trapped between a ca. 1.8 Ga subduction system (Snowbird Tectonic Zone) and coeval terminal collision of the TransHudson orogen in the east, led to rheologic weakening and penetrative deformation in a tectonic vise. EM studies indicate that this deformation likely extended into the lithospheric mantle, a proposition that is currently being tested by teleseismic studies. Older, relatively cold (?) tectonic blocks caught up in this assembly process were affected by small-scale intraplate collisions (ala modern Pyrenees) that led to wholesale accretion and tectonic interleaving, but little internal deformation.

10:00

EXTRUSION TECTONICS IN THE GRENVILLE PROVINCE: SEISMIC, GRAVITY AND STRUCTURAL CONSTRAINTS ON EXHUMATION OF THE OROGENIC ROOT

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The Grenville Province is an extensive zone of continental crustal thickening in the southwestern Canadian Shield which preserves diverse assemblages of high-grade crystalline rocks that experienced a common major tectonothermal event at ca. 1000 Ma. Tectonic slices of high-pressure (eclogite facies) rocks of continental affinity provide a window into the deep-seated workings of the orogen. In 1993, Lithoprobe acquired an oblique 250-km seismic transect in the internal part of the orogen, alongside the Triassic Manicouagan meteorite impact. The seismic profile contains prominent out-of-the-plane reflection zones which originate from adjacent high pressure terranes and bounding fault zones. Exceptionally good agreement between predicted and observed attitudes of reflections, based on shear zones and penetrative strain fabrics along the profile, provided the basis for development of a 3-D crustal model for the Manicouagan corridor. Analysis of crooked segments of the seismic profile and 3-D gravity modeling have also been used as an independent test of the proposed model. A key feature of this model is the presence of an embayment in the southeast tapering Archean (Superior Province) basement, interpreted to extend beneath the region. The size and geometry of this embayment suggests that it may have provided a channel within the Archean basement ramp (rigid buttress) that controlled the rapid extrusion of high-pressure material from the orogenic root.

11:00

RINGED STRUCTURAL ZONES WITH DEEP ROOTS FORMED BY THE CHICXULUB IMPACT

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Deep structures underlying previously recognised ringed zones of the Chicxulub impact crater, as revealed on new deep seismic reflection profiles, demonstrate the diversity of these zones of deformation. The innermost zone coincides with the central peak ring; seismic data show low-velocity (<5 km s-1), chaotically reflective material, interpreted as impact breccia, lying on top of downdropped blocks of pre-impact strata. Normal faults within the Cretaceous strata and deep inward-dipping reflections characterize the middle two deformation zones at radial distances of 55-65 and 85-98 km. Both zones appear to result from the collapse, during the modification stage of crater development, of large (5~25 km radial width) blocks of pre-impact strata uplifted during the excavation stage. Blind thrusts indicated by monoclines in pre-impact sedimentary rocks and deep inward-dipping reflections within the crystalline basement mark the outermost zone of deformation. These monoclines correlate with the small topographic changes at radial distances of 120-135 km noted by previous workers. Restoration of coherent blocks of downdropped pre-impact strata enabled us to better estimate the size and shape of the hole formed in a prominent reflector at 3-4 km depth by the impact. This hole is slightly elliptical along a SE-NW major axis (68 versus 63 km radius). Apparent asymmetries in the other ring zones are more ambiguously constrained by the seismic reflection data.

11:20

CHICXULUB SEISMIC EXPERIMENT: DEEP IMPACT — THE REAL STORY

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The Chicxulub impact crater, which lies partly offshore in Yucatan, Mexico, has been linked to mass extinctions and rapid climate change at the end of the Cretaceous. The crater has been well preserved by rapid burial on a stable carbonate platform and provides a unique opportunity to understand the dynamics and structure of large impact craters. In Fall 1996, we acquired a variety of onshore and offshore seismic reflection and wide-angle-seismic data as part of the UK BIRPS seismic programme. These data image the crater from the post impact basin fill a few hundred metres below the present-day surface, down to the base of the crust at about 35 km depth. The seismic data show that the transient cavity – the original unstable bowl-shaped cavity formed within minutes of the impact – had a rim diameter of about 118 km and a depth of 35 km. These dimensions constrain the main thermal, chemical, physical, and seismic inputs to the Cretaceous environment. The energy released by the impact was about 5 × 1023 J. The most significant immediate global environmental effect is produced by heat radiated from re-entering impact ejecta; the average surface radiation level was about 10 kW/m^2 – sufficient to ignite most surface vegetation and kill all terrestrial animals other than those able to escape underground or into deep water. The dust and especially the sulphate aerosol produced by the impact would have caused a cessation of photosynthesis for a period of about six months, and produced significant global cooling over a period of about 10 years. The consequent collapse of the food chain is probably the major cause of extinctions seen in the oceans. The seismic data reveal Chicxulub to be a multi-ring basin – that is, it has a surface morphology equivalent to that seen in the largest lunar and venusian craters. The seismic data support a model of ring-formation in which power-law breakdown at high stress produces an extremely weak layer in the upper mantle immediately beneath the Moho. If this model of multi-ring formation proves correct, it will allow us to determine crustal thickness on other terrestrial planets and on some of the larger moons of the outer planets.

11:40

NEW INSIGHTS ON THE COLLISIONAL STRUCTURE OF THE PYRENEES FROM *ECORS-ARZACQ* SEISMIC REFLECTION DATA

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The ECORS-Arzacq deep seismic reflection profile crosses the northern Pyrenees and their foreland in the west-central part of the range. The reflection data are combined with surface data and information from other geophysical sources (seismic refraction, gravimetry, seismicity) to construct a crustal cross-section of the entire orogenic belt. The position of Moho reflections and the inferences form the main, near-surface sturctural geometries suggest tectonic wedging as the main thickening mechanism for the Pyrenean crust. A lower wedge of European lower crust and upper mantle has split and indented into the southern, Iberian crust. The lower part of the Iberian crust is underthrust beneath the wedge to be imaged as plunging reflections reaching up to 18 s TWT. In addition, crustal budget considerations based on the imaged geometry and on a palinspastic reconstruction suggest that the Iberian continental root may have been underthrust to depths up to 90 km. An upper wedge of Iberian crust overlies the lower wedge, thus defining a double (stacked) wedge geometry. This upper wedge was delaminated into the upper crustal orogenic prism (above 18 km), which, compared with the ECORS-Pyrenees transect, shows notably less exhumation, the top of the basement nappe stack being preserved form erosion. The indenting European lower crust is recognized along the entire profile with a homogeneous Moho depth of 9-10 s. The signature of the Mesozoic, pre-orogenic extension is preserved there in a 5-6 s thick continental basement under the Arzacq basin, which was not entirely inverted during Pyrenean compression.

12:00

MAGNETOTELLURIC STUDIES IN THE IBERIAN PENINSULA

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Since 1992 a systematic magnetotelluric work has been done in the Iberian Peninsula in order to obtain the geoelectrical signature of the crust and upper mantle in regions with tectonic interest: Pyrenees, Betics and Cantabrian alpine ranges. These MT studies have been carried out along deep seismic reflection profiles (ECORS, ESCI) which allow us to compare the deep structure obtained from both methods. The electrical conductivity models show the presence of high conductivity zones beneath the mountain ranges where thickened crust was delineated by seismic reflexion data and where zones of low velocities were reported by seismic tomography. Althougth other explanations should be considered, the integration with other geological constraints suggests that the deep conductor coinciding with low velocity zones in the Pyrenees and Betics should be related to partial melting zones.

12:20

BRIGHT SPOTS AND GRANITIC MELTS IN SOUTHERN TIBET

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Project INDEPTH has identified a number of anomalously high amplitude reflections, or "bright spots" between 13 and 18 km depth in the Yadong-Gulu Rift of southern Tibet. Found within a broader band of reflectivity (the Yamdrok-Damxung Reflector (YDR)), these bright spots have a negative reflection polarity and produce strong converted P to S phases, suggesting that they are fluid. However, detailed analysis reveals that both focusing and tuning make significant contributions to the measured amplitudes, so special care must be taken in order to infer lithologic properties. Taking such effects into account, we have determined reflection coefficients of -0.4 for two of the bright spots which, in concert with waveform modeling, confirm that they are fluid. Further waveform analysis suggest that two layers of different velocities are involved, possibly filled with different fluids (water or magma or both). High regional heat flow and extensive steam producing hydrothermal activity in southern Tibet support models which include magma as opposed to those involving water alone. One model of magma formation which is consistent with expected Tibetan geotherms involves dehydration of muscovite and the formation of anatectic granite melts at depths of around 25 to 35 km. This is some 10 to 20 km deeper than the observed depth of the YDR bright spots, suggesting that granitic magmas having risen upward to their present position within the YDR. Synthetic seismograms demonstrate that the length scale of these bright spots is compatible with young leucogranites exposed by thrusting in the Himalaya to the south, as well as midcrustal plutons in analogous but exhumed terranes in older orogens such as the Appalachians. In essence, the YDR bright spots represent the juvenile stage of formation of granite terranes within collisional orogens.

12:40

SEISMIC REFLECTORS IN THE MANTLE LITHOSPHERE BENEATH THE BALTIC SHIELD AND NORTHERN TORNQUIST ZONE AND TECTONIC IMPLICATIONS

N. Balling

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The deep seismic reflection profiling techniques have now proven to be able to resolve fine scale structures, not only from the deepest parts of the continental crust and the crust-mantle boundary but also at sub-crustal levels, and sometimes over the whole depth range of continental lithosphere. Seismic reflectors in the mantle lithosphere have been observed beneath the major tectonic units of NW Europe including the Baltic Shield, the Tornquist Zone and the North Sea Basins. Different sets of reflectors are observed including dipping and sub-horizontal events. Dipping reflectors which can sometimes be followed from lower crust and Moho level seem to be generated especially in environments of subduction and collision tectonics. Sub-horizontal events have been observed mainly in the deeper parts of the lithosphere and may develop with preference to the weaker parts of the lithosphere. Beneath the Baltic Shield, in the Gulf of Bothnia, dipping reflectors in the crust and uppermost mantle are interpreted as representing a 1.9 Ga old subduction and collision zone. Similar structures are observed in the southern Baltic Sea indicating the existence of a 1.7-1.8 Ga old fossil active margin. In the southern North Sea dipping reflectors in the mantle lithosphere are suggested to show the existence of a Caledonian subduction and suture zone associated with the closure of the Tornquist Sea between Baltica and Eastern Avalonia. These results demonstrate that structures can survive from early stages of crust-forming processes to great depth and be resolved as seismic reflectors. Such observations are of critical importance for interpreting past crust-forming tectonic processes and for understanding the nature of principal dynamic processes in the crust-lithosphere-asthenosphere system.

THEME 5: Transects and syntheses

8:30

THE SEISMIC FABRIC OF OROGENIC BELTS AND ITS MEANING-CONSTRAINTS FROM EURASIAN OROGENS

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Orogenic belts are best understood in terms of orogenic wedge theory which links the force balance, mechanical properties and mass transfer modes. Recently, orogenic reflection seismic fabrics has been suggested to image these fundamental aspects. However, the complexity of mass transfer modes in natural orogenic belts and their image in reflection fabrics is not yet satisfactory understood. The essential aspect controlling the underlying problem is the question of the processes controlling the formation of the reflection memory of rocks. Analysis shows that rocks in collisional orogenic belts tend to acquire their structural, metamorphic and reflection memory during the same time in the short period of peak metamorphic conditions. Modelling of particle paths has shown that most deformation is accumulated at peak metamorphic conditions during entry of material into a wedge. Rocks will therefore bear a fabric memory related to the accretion mode, site and history. The different modes of mass transfer can be seen to be linked to different types of tectonic structures and metamorphic patterns depending strongly on the geometrical properties of thrust sheets. Evaluation of different examples show that the geometry of reflectivity, structures, and metamorphic pattern image the growth mode of several Eurasian and other collisional belts. Seismic sections across the Variscides, the western and central Alps, and the southern Urals all show these features. Frontal accretion dominates in the external parts while basal accretion controls the more internal zones. In consequence, interpretation of orogenic reflectivity and growth history as well as paleogeographic reconstuctions of these belts have to be revised in several cases.

9:00

THE FORMATION OF CONTINENTAL CRUST AND LITHOSPHERE: A SYNTHESIS BASED ON SEISMIC REFLECTION PROFILING AND GEOLOGIC OBSERVATIONS

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Recent seismic reflection profiles and related geophysical and geologic observations provide new insights into the processes controlling the evolution of the continents. These processes have gradually changed over the past 3.5 Ga primarily due to the decrease in the geothermal gradient in the lithosphere. We discuss these processes in three epochs (I-III): Archean, Proterozoic, and Phanerozoic. (I) Seismic reflection data provide abundant evidence for internal horizontal thrusting within the Archean crust (e.g., Superior, Yilgarn, and Kaapvaal cratons). Although the avereage Archean crust is now about 40 km thick, the original crustal thickness was greater, as evidenced by the exposure of greenschist-to-lower amphibolite grade metamorphic rocks. We estimate an original crustal thickness of 46-52 km. However, high temperatures in the lower crust precluded the granulite-eclogite transformation. Therefore, lower crustal delamination (which is an important process in the Phanerozoic) was inhibited. Isotopic data (Sm-Nd and Re-Os systematics) on diamond inclusions indicate that the Archean lithosphere formed at approximately the same time as overlying crust. However, petrologic evidence indicates that the Archean mantle was 100-150°C hotter than the present day, and thus the Archean lithosphere is more rigid because it repressents the residual of a greater degree of partial melting in the mantle. The evidence appears to favor lithospheric formation as a remnant (restite) of mantle plumes that produced thick oceanic crust (plateaux) and ultramafic extrusions (komatiites). The thick lithospheric keel beneath Archean crust has largely isolated it from further evolutionary processes (i.e., tectonic thickening or magmatic underplating) although most Archean cratons have been rifted at their margins due to the "thermal blanket" effect of their thick keels. Deep seismic reflections from the Archean sub-crustal lithosphere remain elusive, perhaps due to a relatively homogeneous structure. (II) A large body of seismic data exists for Proterozoic crust. Evidence from these seismic profiles, xenolith compositions, isotopic data, and field mapping favor an evolution from accreted oceanic island arcs in an environment similar to modern plate tectonics. Anorogenic magmatism (possibly associated with a superswell that formed beneath the "thermal blanket" of a the Mid-Proterozoic supercontinent) thickened the Proteroizoic crust with felsic and anorthositic upper crustal intrusions and basal crustal mafic underplate. Evidence for this Mid-Proterozoic magmatism is clearly seen in seismic profiles across the Grenville Province, N. America. Strong near-horizontal mantle reflections at depths of 60-200 km have been imaged on several deep seismic reflection profiles across Proterozoic lithosphere (e.g., Great Bear Province, Canada). These observations suggest that Proterozoic lithosphere may have formed by horizontal thrusting and stacking of oceanic lithosphere (lithospheric shingling) for which some basaltic crust remained. In contrast, Archean lithospheric mantle lost most of its basaltic crust before it was accreted to lithospheric keels. Results from thermal modeling, analysis of seismic surface waves, and mantle xenoliths indicate that Proterozoic lithospheric shingling yields a thickness that is approximately 40% less than Archean lithosphere (150-180 km vs. 250-300 km). (III) Some Phanerozoic crust may evolve from the accretion of oceanic plateaux and island arcs, but evidence from crustal Vp/Vs ratios indicate a significantly more felsic whole crustal composition for Phanerozoic crust as compared with Precambrian crust. Guided by recent seismic results, we cite two key processes that produce a felsic Phanerozoic crust. (1) Eclogite transformation/lower crustal delamination: recent seismic refraction and xenolith data (Sierra Nevada, California) indicate that the middle and lower crust of this Mesozoic magmatic arc is not preserved within the crust. These portions of the crust may be present in the mantle as eclogite, or may have delaminated. The granulite-to-eclogite transformation and/or delamination of the middle and lower crust can explain the remarkably low average seismic velocity (6.0-6.2 km/s) crust of the Andes, the Variscides, and Tibetan Plateau. (2) Stacking of subduction/ accretion complexes: field observations indicate that Phanerozoic crust commonly grows by the stacking of accretionary prisms that are quartz rich because their source rocks are the upper crust of adjacent cratons. This process is evident in the vast Eurasian Altaids, the largest region of crustal growth in the Paleozoic era. In summary, seismic reflection profiles recorded during the past 20 years, along with geological observations, indicate significant secular changes in the processes that have formed the continents since the early Archean. These changes are generally related to the gradual decrease in the Earth's geothermal gradient in the past 3.5 Ga.

9:20

DEEP SEISMIC IMAGING OF THE CADOMIAN THRUST WEDGE OF NORTHERN BRITTANY - *GEOFRANCE 3D* PROGRAM

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A newly acquired deep reflection seismic profile (Armor profile), which cuts the Cadomian Domain (600-540 Ma) of northern Brittany, extends the offshore SWAT 10 profile (BIRPS-ECORS program) for describing the regional-scale structure of Cadomian crust. The data were recorded on a Myriaseis telemetric system, using a symmetric split-spread configuration and end-on geometry at the ends to give better coverage, which is around 20-fold. The field data were sorted into slalom-line CMP gathers every 40 m and standard techniques were applied to obtain the stacked sections. Particular attention was paid to enhancing upper-crust information destroyed by the conventional stack process. Upper and lower-crust reflectivity patterns were improved by carefully examining numerous shot gathers, and where single shots showed reflections not seen on the stack, then ray-tracing-modelling was carried out. Coherency-weighted Kirchhoff migration was applied to the stacked section with a constant velocity (5.8 km/s) to restore the seismic image in depth. As such the SWAT 10 - Armor profile gives considerable strength to previous interpretations of oblique-type thrusting for the Cadomian tectonism which had been proposed mainly on the basis of field arguments and supported by gravity modelling. It also demonstrates the regional extent of a thrust wedge at the scale of the whole Cadomian Domain of northern Brittany.

9:40

SEISMIC BOUNDARIES IN THE UPPERMOST MANTLE OF THE NORTHERN EURASIA

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Long range seismic profiles revealed several strong boundaries in the uppermost mantle of the Northern Eurasia. The most stable are the boundaries Nl and N2 observed along the profiles from the Peace Nuclear Explosions (PNE) at depth of 60-110 km. Nl is traced as a good reflector along the QUARTZ profile at depth of 60 km beneath the old Russian Platform, and it dips down to 80-90 km beneath the young Pechora Plate and West-Siberian Platform. A local uplift of N1 boundary is observed beneath the Urals where the Moho has a deep roots. In the East-European platform this boundary is observed along the shorter seismic profiles at depth of 60-70 km (POLAR, EUROBRIDGE). In the Baltic Shield Nl maybe goes up to the Moho where the crustal thickness increases up to 55-60 km. Thus, the data suggest an opposed correlation between the crustal thickness and Nl boundary depth. Nature of this boundary is difficult to explain but its role in the isostatic equilibrium of the lithosphere is clear. N2 boundary has no such a clear correlation with crustal structure. Its depths are more stable (90-110 km), and it often underlies a low velocity zone. This zone and N2 boundary are a bottom of the horizontally inhomogeneous uppermost mantle and may be considered as the mechanical lithosphere bottom.

10:00

EXTRACTING MORE DETAIL FROM REGIONAL TRANSECTS: AN ARCHEAN GREENSTONE EXAMPLE.

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Regional deep seismic reflection data acquired in 1991 from the Eastern Goldfields region, Western Australia resulted in a quantum leap in the geoscience knowledge regarding the structure and evolution of this economically important gold region. It also raised several fundamental questions regarding the granite-greenstone terrane, in particular the relationship between units within the greenstone belts, the possible styles of deformation and the cumulative effects of at least four successive deformations (D1 - D4). Seismically, the main question has become whether it was possible to identify more than the latest deformation(D4), and if yes, then to work back through each successive deformation until we can identify the original D1 events? A more recent re-interpretation of the section indicates that it is possible to unravel the successive deformations. Not only do we identify earlier deformation surfaces but we also show a re-interpretation that supports a thrust stack model of crustal formation. This is based on unravelling the deformation history from the seismic section in conjunction with the identification of the kinematic indicators associated with each particular deformation. In 1997, new higher resolution seismic reflection data was acquired, both at district scale and at mine scale, within a highly prospective greenstone belt with the objective of determining the orientation of several key faults, placing these structures in the regional context and developing a model of the subsurface structure based on the identification of the deformation surfaces. We show that this new data supports the earlier interpretations, however, in parts, it suggests very different tectonic processes have been involved in the formation of the greenstone terrain.

11:00

SEISMIC STRATIGRAPHY OF THE CONTINENTAL LITHOSPHERE

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Deep seismic reflection profiling has had a profound impact on our understanding of structure within the continental lithosphere. However, effective synthesis of this already voluminous and expanding database calls for new approaches to interpretation. One promising strategy is to expand and apply the precepts of seismic stratigraphy developed for sedimentary basins. Much descriptive terminology (e.g. lamellar, transparent) has already been borrowed, though new terms are in order (baroclinal?). However, the key to applying seismic stratigraphy to the full lithosphere is to expand the concept of the "seismic sequence" to include not only depositional (D-type) but intrusive (I-type), metamorphic (M-type) and deformational (S-type) features as well. Since such reflection "sequences" often overprint pre-existing lithology, their definition must rely less on bounding unconformities and more on internal consistency in geometry and seismic attributes. Lithospheric seismic sequences are not synonymous with, but can help define, tectonic "terranes". Of special importance are unique marker horizons; examples include the Moho, bright "spots" and certain mantle reflectors (e.g. Hale discontinuity). Although well control is obviously lacking, other "calibrations" are sometimes available (e.g. xenoliths, receiver functions). Yet the power of such stratigraphic interpretation is that it does not depend upon lithologic identification: key aspects of tectonic evolution can be deduced from spatial relations alone.

11:20

THE ROLE OF A PHASE-CHANGE MOHO IN STABILIZATION AND PRESERVATION OF THE SOUTHERN URALIAN OROGEN, RUSSIA

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Geophysical (URSEIS) and geological data from the Southern Urals form the basis for a model of eclogitization of the Uralian crustal root in Late Triassic to Early Jurassic time, resulting in stabilization and preservation of the late Paleozoic orogenic structure. Lack of a clearly defined reflection Moho beneath the axis of the Southern Urals, corroborated by reinterpretation of wide-angle reflection data, suggests that the Moho is a sub-horizontal gradational boundary at ~50-55 km depth. A subdued (-50 mgal) regional Bouguer gravity minimum across the orogen requires a subsurface load, which we interpret as evidence for eclogitization of the lower crust. Such a metamorphic phase-change would impart a mantle density and seismic velocity to the crustal root, and imply a depth of ~70 km. According to a new crustal-scale restoration of the East European margin along the URSEIS profile, the root zone is comprised of ~70% European crust, and ~30% material belonging to accreted terranes of the hinterland. Timing of eclogitization is constrained by (1) superposition of a flat Moho across the Uralian orogenic fabric, and (2) fission track ages that cluster in the Early Jurassic, marking the end of uplift and erosion. Eclogitization of the Uralian root zone produced an isostatically balanced system with subdued topography, and served to stabilize and preserve the orogenic structure. The post-orogenic evolution of the Southern Urals stands in stark contrast to other orogens, where either delamination of the lower crust and uppermost mantle (Alps, Caledonides), or significant subsidence (Trans-Hudson orogen) occurred as a result of eclogitization of the crustal root.

11:40

THE SOUTHERN URALS TRANSECT - *URSEIS '95* - PRESERVATION AND ORIGIN OF PALEOZOIC COLLISIONAL FABRICS

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The crustal scale seismic image of the Southern Uralide orogen from the vibroseis and explosive-source CMP-reflection profiling of the URSEIS '95 experiment shows a preserved doubly vergent belt with a significant crustal root, as the result of two major partly superimposed collisional events: (1) the development of a Devonian W-facing accretionary complex and (2) a Permo-Triassic collision with the eastward accretion of the Transuralian terranes. While the E-vergent accretionary prism involves the entire crust with the Moho as the basal detachment, the thick-skinned W-vergent structures only include the upper part of the crust, suggesting different rheologies of the plate fragments and collisional processes. Restricted thermal influence across the entire Urals emphasizes that the compositional features of the involved crustal units take the main role: mafic to intermediate rocks dominate in the accreted Siberian island arc and oceanic collage, while the former passive margin of the East European craton is probably controlled by a quartz-feldspar rheology. Correlation with tectonics show the present day bivergent reflectivity as the sum of several orogenic imprints, keeping the memory of highest strain rather than resulting from a progressive and continous collisional process. The orogenic root as defined by wide-angle data is also fairly imaged by the explosive-source reflection data. Gravity and petrophysical modelling suggest that the crustal root is composed of mafic eclogitic rocks with properties close to upper mantle which inhibit prominent Moho reflectivity as in the fore- and hinterland. In contrast to other Paleozoic mountain belts, which suffered substantial tectonic denudation and late- to post-orogenic lithospheric thinning, the Urals evolved near isostasy and never departed far from equilibrium and preserved its collisional seismic patterns.

12:00

THE MOHO BENEATH THE SOUTHERN URALS MAPPED BY PmP AND SmS PHASES

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The Mohoviricic discontinuity appears in the normal incidence URSEIS-95 seismic data as a sharp interface at the West and Eastern edges of the section, beneath the European plate and Siberian Terranes. However the Moho is not imaged beneath the core of the Uralide orogen Magnitogorsk volcanic arc. The wide-angle seismic reflection/refraction component of the URSEIS-9 provided a significantly well resolved image of the crust-mantle boundary. The combination of the P- and S-wave data acquired by the three component geophones place important constraints on the shape, internal structure and possible nature of the Moho beneath the Southern Urals. A P- and S-wave image was obtained by producing a conventional stack after applying a NMO correction without stretch (applying to each trace a constant shift estimated from the hyperbolic moveout equation). The PmP and SmS phases are characterized by low frequencies (1-6 Hz) and their character changes along the transect. The P and S-wave wide-angle stacks feature lateral changes in the seismic Moho large topographic relief, and accurate features suggesting boudin-like structures. High amplitude sub-Moho events characterize the horizontal component supporting that the structural complexity of the Moho can be followed to the upper mantle. This probably reveals that there are important crust-mantle interactions (i.e., equilibration processes) beneath root zone. Geophysical constraints (P- and S-wave velocities, Poisson's ratio and anisotropy estimates) are consistent with a laminated structure of layers of eclogite and mantle material.

12:20

MEASURING THE SEISMIC PROPERTIES OF TIBETAN BRIGHT SPOTS: EVIDENCE FOR FREE AQUEOUS FLUIDS IN THE TIBETAN MIDDLE CRUST

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Seismic images of basement bright spots are commonly interpreted to mark the presence of fluid concentrations. However, the nature of the fluids imaged (melt or aqueous fluids) is usually inferred from circumstantial evidence of the geological setting. A band of bright-spot reflections has been imaged by Project INDEPTH (International Deep Profiling of Tibet and the Himalayas) at about 15 km depth along 150 km of the northern Yadong-Gulu rift, southern Tibet. We analyzed the reflection amplitude variation with offset (AVO) of P- and P-to-S-converted reflections observed on INDEPTH three-component wide-angle seismic data. We observe that the angle at which the P-wave reflection amplitude reaches a minimum is indicative of the relative change of P- and S-wave velocities at the top of a low-seismic-velocity unit. Also theoretical rock-physics bounds, the Hashin-Shtrikman bounds, constrain the range of possible P- and S-wave velocities of an isotropic fluid-saturated rock. Thus we constrain both the P- and S-wave velocities of the Tibetan bright-spots to 3.0±0.5 km/s and 1.6±0.5 km/s, respectively, and conclude that these velocities provide direct evidence for the presence of free aqueous fluids in the Tibetan bright spots. Moreover, the wetting properties of aqueous fluids in crustal rocks require c. 10% volume of fluids to produce our seismic observation. Our results suggest that in continental middle crust Vp/Vs ratio is not a good measure of the presence of aqueous fluids, and that P-wave reflection coefficient ?-0.4 is unlikely to be produced by the presence of melt. The presence of relatively large quantities of free aqueous fluids, presumably mostly saline super-critical H2O, does not preclude the presence of melt, but constrains the maximum temperature at the Tibetan bright-spots to the wet granite solidus (c. 650°C), and thus the maximum surface heat-flow to ~110 mW/m^2. The observed southern Tibetan bright spots can be explained as cooling melt bodies in a hot crust, or alternatively as a result of transient flow of aqueous fluids through a lower temperature and lower heat-flow crust. The mechanical implications of the two models still need to be examined, but may not be remarkably different.

15:00

LITHOPROBE: RECENT RESULTS AND FUTURE PLANS FOR REVEALING THE EVOLUTION OF A CONTINENT

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Since 1984, LITHOPROBE has acquired many thousands of kilometers of multichannel reflection data as one major component of its multidisciplinary, collaborative research program to reveal the evolution of a continent. Another major component is the acquisition of seismic refraction/wide-angle reflection (R/WAR) data. Since 1996, a reflection survey and a R/WAR survey have been acquired in each of LITHOPROBE's Western Superior Transect (WST) and Slave-Northern Cordillera Lithospheric Evolution Transect (SNORCLE). The WST, an area dominated by a pattern of east-west trending lithotectonic belts within the largest component of the Precambrian nucleus of North America, provides a unique laboratory for investigating processes involved in the formation, assembly and stabilization of Late Archean lithosphere. The 1996 R/WAR survey indicates average P- and S-wave crustal velocities higher than average values for Archean crust, a relatively low VP/VS ratio, and azimuthal anisotropy in the upper mantle. Preliminary results from the 1997 reflection survey, totaling 800 km, indicate high quality data that provide good images of subsurface structures. The SNORCLE Transect investigates the structure and growth cycles of continental lithosphere, and the processes associated with those growth cycles, in northwestern Canada, one of the few regions on Earth where the rock record spans 90% of Earth history [from the oldest rocks at 4.0 Ga to Neogene volcanism]. A 725 km long reflection survey, recorded across the Precambrian elements of the southwestern Northwest Territories in 1996, shows spectacular evidence for crustal delamination and concomitant structure within the upper mantle. The 1997 R/WAR survey, with profiles over all tectonic elements of the transect, provides crustal velocity information; more specifically, the profile coincident with the reflection survey shows velocity structure in the upper mantle consistent with geometry from the reflection image. As LITHOPROBE heads toward completion in 2003, an additional 350 km of reflection data in WST and 1500 km of new data in the Northern Cordillera domains of SNORCLE will be recorded. All of the reflection data are being prepared at the LITHOPROBE Seismic Processing Facility (Univ. of Calgary) for inclusion in a LITHOPROBE Seismic Atlas of Canada; see the LSPF web site [http://www.litho.ucalgary.ca/atlas/atlas.html] for developments in this component of the planned LITHOPROBE synthesis of scientific results.

15:20

REGIONALLY VARIANT SEISMIC IMAGES OF THE WESTERN MARGIN OF THE TRANS-HUDSON OROGEN

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LITHOPROBE and COCORP crustal reflection surveys crossed the western segment of the THO and the region of the bounding western craton, several hundred km apart, in a number of localities. The resulting seismic sections exhibited several line dependent seismic signatures illustrating regional differences of the orogenic processes along a south to north direction of the collisional belt. The lithosphere, beneath the crust is in general seismically transparent but there are a number of localities with clearly recognizable reflectivity, north of latitude 54°, indicating regional lithospheric involvement in the tectonic development. Within the western part of the orogenic belt the Moho is always a strong reflector, characterized by distinct but simple wave forms. Under the craton, with the exception of Line S2B, the same mantle-crust contact, is recognized by weak, marginal reflection and associated complex seismic signatures. The amplitudes of seismic signals, throughout the lower crust, are high and marked by strong subparallel, laterally well traceable zones of reflection patterns.The exception is the southern part of Line S2B where the comparable lower crustal signatures are altered by a gentle southeastern dip. Within the upper crust, short dipping patterns of reflectivity suggest complex brittle deformation. The regionally distinct nature of these seismically defined structures implies involvement of variable collisional processes along the strike of the margin of the orogen.

15:40

ACCRETIONARY TECTONICS IN THE LATE ARCHEAN? FIRST RESULTS FROM THE *LITHOPROBE* WESTERN SUPERIOR TRANSECT

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The Superior Province of North America constitutes the world's largest block of preserved Archean lithosphere, and thus provides an ideal location for studying Archean lithospheric evolution. A model of modern tectonic terrane accretion has been proposed for the western Superior Province in NW Ontario in which oceanic crust, island arcs, sedimentary prisms and continental fragments were accreted successively against the southern margin of an old (> 3.0 Ga) cratonic nucleus during ca. 2.7 Ga orogeny. In the fall of 1997, LITHOPROBE acquired 800 km of 32 s vibroseis seismic reflection data along a N-S corridor across the Western Superior Transect area. Crustal reflectivity is prominent along the entire profile with the reflection Moho gradually increasing in depth from 12 to 14 s moving southward away from the cratonic nucleus. The cratonic nucleus is characterized by S-dipping reflections that can be traced from the near surface to the lower crust where they appear to be truncated by N-dipping reflections along the southern boundary with the "accreted terranes". N-dipping reflectivity dominates within the zone of accreted terranes, with shallowly N-dipping reflections observed within the lower crust and possibly into the uppermost mantle. These preliminary observations do not contradict proposed models of Archean accretionary orogenesis for the western Superior Province.

THEME 6: Seismic reflection applications to natural resources and environment

16:30

RECENT INNOVATIONS IN ENGINEERING-SCALE SEISMIC REFLECTION SURVEYING

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Over the past two decades, shallow seismic methods have played an increasingly important role in assessing and resolving a wide variety of engineering and environmental problems. The utility of such methods have been demonstrated in investigations associated with nuclear waste disposal in crystalline rocks, mapping small-scale structures in surficial sediments, locating tunnels, and determining depths to the groundwater table and bedrock surface. Recently, we have introduced new techniques to reduce significantly data acquisition costs, improve the reliability of subsurface images, and extract information on subsurface elastic parameters from certain "noise" components of seismic shot gathers. To increase the speed and efficiency of shallow seismic data recording, a towed land streaming containing self-orienting gimbal-mounted geophones has been constructed. Initial experiments demonstrate that good coupling with the ground may be achieved when the geophones are contained in heavy casings. Shot gathers and stacked sections recorded with the gimbal-mounted are practically indistinguishable from those recorded with conventional spike geophones. Although profiles are often sufficient for mapping simple and continuous geological features, reliable knowledge of the size and geometries of complex reflectors may be difficult to obtain on the basis of sparse 2-D data sets alone; out-of-the-plane reflections and diffractions may lead to serious mis-interpretations. We have designed and tested a comprehensive acquisition and processing scheme that provides complete and unaliased 3-D images of the subsurface. These images allow subtle features in the surficial sedimentary section to be mapped from approximately 15 m depth to the bedrock boundary, which in the studied area varies between 100 and 200 m depth. In most seismic investigations, guided and surface waves are regarded as noise. By transforming entire seismic shot gathers into the phase-velocity versus frequency domain, it is possible to determine the depth and lateral distributions of both P- and S-wave velocities. If density information is available, it is then a trivial matter to compute estimates of the classical elastic parameters.

17:00

PROGRESS IN STUDYING PRECAMBRIAN CRUST BENEATH CONTINENTAL INTERIORS FROM SEISMIC REFLECTION: USA MIDCONTINENT

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Newly available industry reflection data provide critical constraints on understanding the structure and origin of crust beneath the central USA Midcontinent and the seismotectonic framework north of the well-known New Madrid Seismic Zone in the central Mississippi Valley. These data are providing exciting new insights on supracrustal Proterozoic assemblages and on mid-to-lower crustal structures that govern earthquakes beneath continental interiors. Mapping of the reflector sequences in the upper-to-middle crust furnishes, for the first time beneath the Midcontinent, a broad 3-D perspective of the structure of Precambrian "basement". Highly coherent basement reflectivity, first seen on COCORP transects, is expressed as a broad bowl-shaped assemblage with a minimum thickness of 5.3 km situated beneath the center of the Paleozoic Illinois Basin, a large typical intracratonic basin. The boundaries of this sequence are marked by distinct steeply dipping reflections (possible thrust faults) that continue or project up to antiformal disruptions of lower Paleozoic marker reflectors implying Paleozoic or possibly later tectonic reactivation of Proterozoic structure. The areal extent of the sequence appears to correspond generally to an anomalous concentration of large magnitude upper-to-middle crustal earthquakes. Various types of associations have been recognized between earthquake source parameters and structures in reflection profiles. The most spectacular of these relationships consists of moderately dipping high-amplitude mid-crustal reflections, interpreted as compressional tectonic structures, that correspond to earthquake hypocenters (e.g., 1968.11.09 mbLg=5.5) with a reverse fault focal mechanism. Multiple hypotheses are admissible for the origin of the Proterozoic reflectivity, including basaltic flows or sills interlayered with clastic sediments and/or emplaced within felsic igneous rocks. Such an explanation is analogous to nearby Keweenawan rift-related volcanism and sedimentation, which initiated during Proterozoic rifting, followed eventually by reverse faulting along the rift margins caused by Grenville compression.

17:20

3D SEISMIC PROFILING FOR MINERAL EXPLORATION

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The Sudbury Basin and the Matagami anticline of the Canadian Shield were selected for conducting the world's first 3-D seismic surveys for deep base-metal exploration. The 3-D seismic experiments confirm that in a hardrock environment, massive sulfide bodies cause a characteristic seismic scattering response. This provides an excellent basis for the direct detection of deep massive sulfides in the crystalline crust by high-resolution seismic methods. We review the physical rock properties of massive sulfides, discuss the seismic reflection response of deep seated ore bodies, and present borehole geophysical data from the site selection process. Examples will illustrate various stages of the ambitious hardrock exploration project: from survey design to heliportable data acqusition and from special processing considerations to final interpretation of the 3-D seismic data volume. Special attention must be paid to improved static corrections, in order to enhance images of seismic scatterers. In addition, velocity and density logs must be obtained for detailed interpretation of 3D seismic images. A comprehensive calibration and groundruthing program has been initiated to further guide the development of this new exploration technology for the crystalline crust.

THEME 7: Seismic Techniques: new developments

8:30

DEVELOPMENT AND FUTURE OF IMAGING THE LITHOSPHERE

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The use of controlled source methods to image structure in the lithosphere have made significant strides over the past 25 years. As with all new techniques, major improvements were made quite quickly; the change from the first rather fuzzy profiles to clean sections with reflections from 28-30 s two-way time (80-100 km depth) occurred within the first 10 years. However, it was soon realised that to acquire just an image was not going to answer all the issues that deep reflection profiling had raised. In particular, the causes of the observed reflectivity required more information than available from two-way travel-time alone. This need drove the development of the stand-alone data logger capable of long deployment in remote areas recording all the shots used during a survey often at long offsets. These long offset data provide critical velocity information that can help with the imaging of the reflection data and can be used to get estimates of physical properties of rocks that lie beyond the reach of the drill. Though much of these long offset data are processed and interpreted in isolation, modern inversion methods are now using these data in conjunction with near-normal incidence data to produce a common model. New acquisition tools are being developed, e.g. vertical hydrophone arrays, and these will be used for future surveys. Equally more powerful processing tools will be used to extract more from the received signal. Together these developments are opening new opportunities for imaging the lithosphere in more difficult areas and getting better estimates of the properties of the lower crust and upper mantle.

9:00

FULL -WAVEFIELD SEISMIC INVERSION — BEYOND RAY-TRACING

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Conventionally, wide-angle data in laterally varying structures are inverted using ray-tracing of arrival-times only. Unfortunately wide-angle wavefields are generally exceedingly complex, consisting of a number of conflicting and interfering seismic phases. Travel-time methods, based on arrival-time picks and ray-tracing are fundamentally limited by these interference effects. We have found however that these arrivals can be usefully inverted using full-wavefield finite-difference frequency-domain inversion methods that have previously been successfully employed to reconstruct high resolution images from cross-borehole seismic data. The resulting velocity images are significantly better resolved than travel-time reconstructions, approaching seismic migration methods in resolution, while retaining the quantitative results obtained by tomographic methods. We show three applications of increasing complexity: 1. inversion of shallow wide-angle data from the Chicxulub seismic experiment in which full-fold wide-angle data were acquired on a single 6-km streamer. 2. inversion of wide-angle data from the two-ship BIRPS SLAVE profile, shot in 1986, in which full-fold wide-angle data were acquired continuously to offsets of 16 km. 3. inversion of wide-angle data from a commercial multi-ship profile, shot to image beneath complex overburden, in which full-fold data were acquired to offsets of 30 km. The technique has now been developed to a point where it can be realistically applied to full-fold crustal-scale data.

9:20

ESTIMATING THE STATISTICS OF CRUSTAL REFLECTIVITY: THE ROLE OF SEISMIC BANDWIDTH.

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As reflections in the deep crust cannot readily be traced to known geological features, a recent approach has been tried to derive statistical measures from seismic data as a means of quantifying deep geology. Typically we can estimate scaling measures (for example, horizontally) through power spectral estimates as a function of frequency. This type of analysis usually yields characteristic heterogeneity scale lengths (correlation distances) of several hundred metres. As the correlation distance plays a fundamental role in controlling fluid migration and crustal strength, by placing a limit on power law scaling in the crust, an accurate estimate of this statistic is essential for interpretations of crustal processes. Here we show that seismic bandwidth exerts a central control on estimates of correlation lengths in the crust. By combining wave simulations, super-deep borehole data and theory, we conclude that there is no reliable evidence for `short' (hundreds of metre scale) crustal correlation distances. The consequences of this finding for interpretation of crustal processes will also be discussed.

9:40

A NEW METHOD FOR ANALYSING DENSELY-SAMPLED WIDE-ANGLE SEISMIC DATA

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Wide-angle seismic surveys of the continental shelf are being acquired with progressively denser spatial sampling, either through the use of large numbers of ocean bottom seismometers and an airgun source, or by using two ships in a synthetic-aperture profile. Conventional ray-tracing and travel-time inversion methods are pushed to their limits by there massive datasets, and new tomographic, waveform inversion and migration techniques are being developed to exploit their full information content. However, at the moment, all new methods either require picked travel-time data that has been allocated to a particular seismic phase, or a starting model close to the final model, which will in turn have been built using this information. This process involves two subjective steps - travel-time picking and phase allocation - both of which directily affect the velocity model built from the data. We present a new method for mapping wide-angle arrivals into a two dimensional tau-p domain, that produces a velocity map directly form the seismic data. At present, it is implemented for travel-time data, so that the picking step is still present, but the allocation for seismic phase has been eliminated. The use of simple geometric relationships between reversed raypaths gives a robust framework for the incorporation of unreversed data. The final model consists of a mosaic of independent velocity values projected into an appropriate horizontal position, and plotted against tau (time), which it turn can be downward-continued into depth. The next step will be to extend the technique to the use of tau-p inversions of the seismic data itself, so that travel-time picking becomes unnecessary.

THEME 8: Rifts, basins and extensional provinces

10:40

RIFTS, BASINS AND EXTENSIONAL PROVINCES

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Deep penetration reflection profiling and long-offset reflection/refraction seismology have played key roles in exploring the processes of continental extension and the generation of new oceans. Such studies have shown that volcanism is an important part of the rifting process at most, rather than only some, rifted continental margins. Seismic and other studies have shown that rifting proceeds, not by either pure or simple shear alone, but by a spatially and temporally varying combination of the two. Seismic studies have shown glimpses of possible fluids (magma, water or something else) in the middle and lower crust. The role of fluids on the processes of rifting, although universally recognized to be profound, are poorly understood and have not been incorporated into currently accepted models for the rheology of continental lithosphere. Rifts are inherently 3-D structures, and therefore seismic studies of rifting must move increasingly toward the use of 3-D reflection technology, particularly in the marine environment where it can be employed using resources currently available to the academic community. Understanding rifting on the scale of the continental crust and upper mantle requires that we be able to map the lateral variations in the thickness of the brittle and ductile parts of the crust. This is most likely to emerge from studies of velocity obtained using long-offset methods combined with textural information from reflection profiling. Seismic studies of rifted continental margins must increasingly take account of the conjugate margin and must examine the along strike variation of the rifting geometry. Seismic methods must be used effectively in conjunction with surface geology, drilling, and numerical simulation to increase our understanding of the way continental crust stretches and breaks.

11:10

EXTENSIONAL TECTONICS AND CRUSTAL REFLECTIVITY: THE EXAMPLE OF THE NORTHERN APENNINES (ITALY)

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Recently acquired deep seismic reflection profile CROP 03, together with other geophysical data, allow a better understanding of the extensional tectonics occurring in the western part of the Northern Apennines (Italy). Seismic data show that a dominant role in the extensional phase is played by a system of low angle eastdipping normal faults, bordering the main neogenic basins and developing on the forelimb of antiformal stacks formed during the compressional stage. Commonly these faults display in their hanging wall a set of conjugate antithetic normal faults. This system seems to get younger eastward as it approaches the Apenninic chain. Evidence from the seismic data also reveals that some of these shear zones affect all of the lower crust where they are characterized by several, short and anastomozed reflectors. As a result of the extensional tectonics starting with 13Ma, crustal emplacement of granitic bodies has taken place. In some cases the magma appears to be intruded at the footwall of the main faults, bending the fault itself and following the same pattern of younging of the faults system. This suggests a relationship between the faults and magma intrusions, meaning that decompression at the hanging wall of the fault made the magma, localized at its foot wall, to intrude and to cool. The high amplitude reflector, located at 5 seconds (TWTT) on the CROP 03 profile, along the projection of the magma body of the M.Amiata geothermal field could be a seismic expression of these magma bodies or the related fluids . This interpretation has been applied to similar reflectors observed in other extensional provinces of the world.

11:30

POLONAISE'97- SEISMIC PENETRATION INTO LITHOSPHERE OF THE POLISH BASIN

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The Polish Basin forms the most eastern part of the Permian - Mesosoic Basins of the Central Europe along the Trans European Suture Zone (TESZ), the most important geologic boundary in Europe north of the Alpine orogenic belt which begins at the western edge of the Precambrian East European Craton. A large seismic experiment, completed in Poland in May 1997, targeted the deep structure of the TESZ and the complex series of upper crustal features associated with it. The POLONAISE'97 is perhaps the largest entirely land-based lithospheric experiment ever undertaken, with 613 instruments being deployed to record in 3-D system 63 big shots along 5 profiles with a total length of about 200 km, included contributions from geological communities in Poland, Denmark, the USA, Lithuania, Finland, Sweden, Germany, and Canada. First results show that the crustal thickness near the TESZ is intermediate between that of the Precambrian Craton (~42 km) and the Palaeozoic platform (~30 km). In the Polish Basin the depth to the consolidated basement characterised by 5.8-5.9 km/s velocity is 8-12 km. Below the basement velocities are very low, and at a depth of about 20 km are less than 6.0 km/s.

11:50

DEEP STRUCTURE OF THE NORTHEASTERN PART OF THE EAST-EUROPEAN CRATON

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Seismic model of the northeastern part of the East-European Craton have been developed based on the results of recent wide-angel reflection/refraction experiments carried out by the GEON Centre. Analysis of themaps showing distribution of the body wave velocities, silica content and thickness of the upper, lower and entire crystalline crust permits to determine the existence of an anomalous zone, which is 150-250 km wide, 1500 km length, and approximately coincides with the 42 degrees east longitude. Features of this zone and adjacent areas (Moho uplift, lower crust thinning, chemical composition changing, low bodywave velocities in the upper crust, and uppermost mantle and so on) imply that it is a palaeorift. Smaller Riphean rifts (the most part of aulacogens) are branches of the major system and continue into the interior parts of the crustal segments.

12:10

A NEW PASSIVE MARGIN MODEL FOR THE NEOPROTEROZOIC AND EARLY PALAEOZOIC OF SE AUSTRALIA DERIVED FROM SEISMIC STUDIES OF TASMANIA

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The island of Tasmania in southeast Australia has a number of geological elements. The relationship between these elements is largely obscured by younger cover of the Tasmania Basin, including extensive dolerites which limit the ability of potential field techniques to map basement. Therefore the development of a robust tectonic model for Tasmania has been inhibited. A seismic program was undertaken to map the large scale structure of Tasmania at depth. Deep seismic profiles were collected offshore along the entire coastline; the airguns were also recorded at a number of seismographs deployed across the island, allowing low resolution 3D tomographic imaging. Short reflection profiles were also recorded onshore across structures which could not be imaged by the offshore profiling. The Proterozoic basement in the northwest and in the Tyennan Block in the core of the island is unreflective, except for mostly east dipping reflectors which project to the surface at block boundaries. In the east, however, the lower crust is broken into rotated blocks whose boundary faults are reflective, indicating progressively greater crustal extension of the Tyennan Block to the northeast, where a reflective lower crust is interpreted to be highly extended continental crust with passive margin sediments and possibly fragments of oceanic crust. The apparently complex geology of Tasmania therefore fits into a simple tectonic model in which several episodes of crustal extension occurred before oceanic crust formed to the northeast. The extended crust has now been inverted, probably from the northeast.

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Deep Seismic Profiling of the Continents and their Margins

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Spain

Abstracts

Poster Presentations

POSTER PRESENTATIONS

THEME 1: Active/Passive Margins

T1-01

INTEGRATED OCEAN-BOTTOM SEISMOGRAPH AND CONVENTIONAL REFLECTION STUDIES IN THE PETREL SUB-BASIN AT THE AUSTRALIAN NORTH WEST SHELF

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Refraction/wide-angle seismic studies with ocean-bottom seismographs (OBSs) in the Petrel sub-basin were a part of a broader OBS survey undertaken by AGSO along 5 profiles on the Australian North West Shelf. One of main scientific goals of this project was to understand better the origin of reflectivity seen in the conventional reflection data, particularly in the deep crust. Prominent reflectivity seen in the conventional reflection data at two-way times (TWT) greater than 4 s does not correspond to any velocity increase imaged by refraction/wide-angle techniques. The most significant velocity increase which occurs in the Moho does not produce high-amplitude near-vertical reflections. Interval velocities estimated from the conventional reflection data at TWT greater than 2 s appear to be up to 1 km/s lower than those derived from the OBS data. If the former are used to depth convert reflection data, then depth to seismic boundaries in the centre of the basin at TWT 6-9 s would be underestimated up to 2 km. A preliminary estimate of the petrology of the deep crust and upper mantle in the region shows that mafic underplate is unlikely to be present in the lower crust. Rocks of the ultramafic composition will have seismic velocities close to those observed underneath the Moho even where it is as shallow as 20 km depth.

T1-02

VELOCITY STRUCTURE OF THE ARGO ABYSSAL PLAIN, NORTH WEST SHELF OF AUSTRALIA

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Ocean bottom seismograph data from two orthogonal transects were analysed to determine and model the crustal structure of the Argo Abyssal Plain in the northeastern Indian Ocean. The AGSO research vessel 'Rig Seismic' was used to deploy the OBS receivers and provide airgun shots every 100 m from a 4800 in3 sleeve gun array. The transects were coincident with previously acquired reflection seismic lines. Two-dimensional travel time modelling indicates that the west portion of the study area is associated with unusually high velocities (7.3 - 7.4 km/s) for oceanic layer 3. These high velocities are not consistent with gabbroic composition, but may indicate serpentinite alternating with ultramafic material. The data show very good shear wave arrivals which can be used to discriminate between these two compositions as serpentinite has very different shear velocities compared to most other materials. Low angle dipping reflectors are imaged in the crust near ODP site which in some places penetrate nearly the entire oceanic section. Clear 'P' basement refractions and 'PmP' reflections are observed on the strike line at this site. Significant features are a 7.4 km thick crust and a velocity of 7.3 - 7.4 km/s at the base of the crust. The reflecting surfaces dip at 30°-35° and may be low angle detachments between the upper crust and the lower crust/mantle. These low dips could be explained by the lubricating presence of serpentinized peridotite, which has been dredged from here. They may also represent failure surfaces in serpentine-lubricated landslide zones.

T1-03

THE CRUSTAL STRUCTURE OF A PASSIVE MARGIN: A TRANSECT ACROSS THE AUSTRALIAN NORTH WEST SHELF

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Ocean bottom and land seismometers were deployed along a 720 km transect extending from the onshore Kimberley to the Argo Abyssal Plain. The refraction traverse is coincident with deep reflection seismic lines recorded to 16 seconds two-way-time. This, coupled with gravity data, was modelled to provide a section 950 km long and 70 km in depth. A major transition from an average crust to a highly thinned crust occurs geographically at the transition between the Proterozoic shelf and the main Mesozoic Basin. The crust thins rapidly over 50 km section from 37 - 25 km with the Moho bowing upwards. The area of thinning is coincident with upper crustal discontinuities; block faulting extends from the Mesozoic Basins into the lower crust and reactivation is demonstrated. Velocities of 5.8 - 6.0 km/s in the upper crust are probably reflecting granite composition. A pod at the base of the crust, inmediately eastwards of the discontinuities, is anomalously thick and has a velocity of 7.0 km/s which may be indicative of underplating. Paleozoic tectonic events shaped the container for Phanerozoic deposition as established from the westward thinnig of the margin during the Mesozoic depocentres. The lower crust may have undergone brittle deformation as demonstrated by presence of possible shear planes interpreted on seismic. A deepening of the simple to pure shear transition zone may be a characteristic of passive margins.

T1-04

CONTINENTAL MARGIN TRANSECTS IN THE CENTRAL GREAT AUSTRALIAN BIGHT

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The southern margin of Australia is a divergent, passive, continental margin extending for some 4000 km from the Naturaliste Plateau in the west to the South Tasman Rise in the east. The margin formed between the Late Jurassic and the Tertiary during the rifting that led to the separation of Australia and Antarctica, and has long been considered a classic example of a rifted margin. In 1997, the Australian Geological Survey Organisation acquired two 600-km-long deep-seismic transects and a grid of shorter lines in the Great Australian Bight, encompassing the range of tectonic settings from unextended continental out to oceanic crust. In this area reflection Moho occurs at about 11.5 s TWT, and generally shallows southwards towards a complex high that separates highly extended continental crust from faulted, probable slow-spreading oceanic crust. The western transect across the Eyre province illustrates the upper crustal extension of the 'perched' Eyre Sub-basin system with its well defined half graben and ?Late Jurassic-Early Cretaceous synrift section. To the south, much of the deepwater Recherche Sub-basin appears to be underlain by very thick, relatively undeformed section. This area has clearly been subjected to substantial full-lithosphere thinning. In this western province there is good correlation between the various crustal zones imaged on the transect and the satellite gravity data. From north to south these zones represent upper crustal thinning, full-lithosphere thinning, old slow-spreading oceanic crust, and younger 'normal' oceanic crust. The eastern transect across the Ceduna province illustrates a very different extensional style with significant upper crustal and deep thinning occurring beneath the Ceduna Terrace. In this province the direct equivalent of the Recherche Sub-basin zone appears to be missing, and the old slow-spreading oceanic crust zone is much narrower. Beneath the inner Ceduna Terrace about 4-5 s TWT (7-9 km) of largely Cretaceous section overlies a Neocomian surface; Tertiary sediments are very thin throughout much of the area.

T1-05

CRUSTAL STRUCTURE UNDERPINNING THE OTWAY BASIN, SOUTHEAST AUSTRALIA: A PASSIVE MARGIN BASIN IN A STRIKE-SLIP SETTING

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The Otway Basin underlies the continental shelf and slope towards the eastern end of Australia's Southern Rift System (SRS) and formed during the Jurassic-Tertiary rifting and separation of Australia and Antarctica. The regional tectonic setting indicates that the basin formed primarily in a strike-slip environment. Deep-seismic data (16 s record length) acquired by the Australian Geological Survey Organisation in 1995 clearly image the major crustal structures that underpin the basin and its margins.The landward flank of the basin is characterised by strongly laminated lower crust that thins basinward over a distance of some 50 km and is absent beneath the main basin depocentre. This suggests that accommodation space in the basin was generated by the extension and removal of much of the lower crust so that mid-crustal rocks may now directly overlie mantle beneath the main basin depocentre. This could account for the anomalously strong reflection Moho which is recorded in this area.The seaward flank of the basin is characterised by several zones with highly distinctive structuring styles. From landward to seaward, these zones comprise:.- Strong relief in the deep crust and upper mantle, with relief of up to 4 km at the Moho over a horizontal distance of less than 20 km. This relief largely appears to be controlled by shearing and/or magmatism and has influenced the distribution of the overlying Cretaceous-Tertiary section.- Detached and overthrust packets of Mesozoic sediment, several kilometres in thickness, which are underlain by extremely thinned continental crust that is probably less than 2 km thick.- Outer margin basement highs standing several kilometres above the adjacent basin. These highs are ubiquitous along the SRS and are probably a product of the mode of margin formation.

T1-06

VELOCITY MODEL BETWEEN TIMOR AND AUSTRALIA FROM SEISMIC AND GRAVITY DATA

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As a part of a regional study of Australia's North West Shelf, the Australian Geological Survey Organisation acquired an extensive grid of deep crustal multi-channel seismic reflection data, supplemented by gravity measurements and wide-angle seismic refraction data collected with ocean bottom seismometers. The study presented here examines a 340 km transect across the Vulcan Sub-basin on the continental shelf, and trending NW-SE between Australia and the island of Timor. The deepest reflection observed on this line is a prominent mid-crustal event at 6 s TWT, while the refraction data includes arrivals from the upper mantle. The seismic data have been interpreted to give a velocity-depth model consistent with the gravity data. Crustal thickness is about 35 km at the landward end of the transect, 23 km in the middle of the transect, and 30 km in the NW of the transect. Lateral and vertical velocity gradients within the crust are large where it is thinnest, and suggest that lower crustal extension has occurred. At the landward end of the line, the Kimberley Block has a velocity of 6.4 km/s, while the thin crust varies in velocity from 5.8 - 7.5 km/s. The high velocities are localised, and may represent underplating and/or mafic intrusives in the extended lower crust. The 6 s reflector does not coincide with any refraction boundary, and is interpreted to be a horizontal shear zone within a single lithological unit. Sub-Moho events in the refraction data have apparent velocities exceeding 8.4 km/s and their interpretation is problematic.

T1-07

CRUSTAL STRUCTURE IN NORTHERN AND EASTERN TASMANIA FROM SEISMIC REFRACTION DATA

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In 1995, AGSO's research vessel Rig Seismic acquired a continuous set of reflection profiles around Tasmania. The shots were recorded by a network of 44 recorders distributed throughout the island, resulting in a 3-D refraction and wide-angle reflection dataset. Preliminary 1-D models indicate a crustal thickness of approximately 31 km along the western north coast and 27 km along the eastern north coast, east of the Tamar Fracture System. Down the east coast, the thickness is relatively uniform at 25 km, increasing by several km near the Freycinet Peninsula in the south. Data from further inland suggest that the crust thickens towards the centre of the island. The crust appears to be composed of two main layers, with the mid-crustal interface occurring at about 8 km depth in the north and 10 km depth in the east. Upper crustal velocities (P1) are typically about 5.7 km/s, lower crustal velocities (P2) are around 6.3 km/s and mantle velocities (Pn) are 7.8 - 8.0 km/s. These results indicate that Tasmania's crust is thicker than has been suggested by previous seismic and gravity studies. The most prominent lateral feature of a 2-D crustal model constructed for the western north coast is an upward deflection of both the Moho and the mid-crustal interface in the vicinity of the Arthur Lineament, a belt of regionally metamorphosed rocks. Our long term goal with this very large dataset is to invert traveltimes for 3-D crustal structure and velocity to produce a tomographic image of the whole island to at least Moho depth. Such an image will enhance our current understanding of Tasmania's deep geology and tectonic evolution.

T1-08

CRUSTAL STRUCTURES OF THE PHILIPPINE SEA PLATE NEAR TAIWAN ARC-CONTINENT COLLISION ZONE

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The complicated western boundary of the Philippine Sea plate is defined from north to south by the northwestward subduction along the Ryukyu arc-trench system, arc-continent collision on Taiwan, and eastward subduction of the Eurasian plate along the Luzon arc-trench system. High rates of seismicity observed in eastern Taiwan and its offshore region clearly indicate that the western corner of the Philippine Sea plate near Taiwan is undergoing active deformation. Results from recent multichannel seismic reflection surveys and the TAICRUST deep seismic imaging survey have provided new insights into the crustal structures and deformation along the plate boundary of this arc-continent collision zone. Wide-angle reflection/refraction data recorded by ocean bottom seismometers (OBS) east of Taiwan and onland instruments deployed across the Coastal and Central Ranges on Taiwan, suggest an abnormally thick oceanic crust (about 15 km in thickness) underlain the Huatung Basin east of Taiwan. Crustal thickness increases rapidly to the west starting from the eastern flank of the Luzon Arc and reaches 50 km under the Coastal Range, indicating thickening of the Philippine Sea plate due to arc-continent collision processes. Seismic reflection profiles in the Huatung Basin show thick (1 to 3 s TWT) sedimentary strata lying on top of oceanic crust. Beneath these strata, the basement surface exhibits large-scale relief and is underlain by mid- and lower crustal reflections, all of which may reflect deformation of the oceanic crust. However, the overlying sediments are little deformed. A prominent unconformity is observed in the northern Huatung Basin that acts as a basal detachment for the upper sedimentary layer showing gravity-sliding structures. Folds and east-verging thrusts are observed only along the eastern flank of the Luzon Arc. From the velocity model and seismic reflection images, crustal thickening appears to be concentrated within the Luzon Arc, or in the lower part of the oceanic crust along the western edge of the Philippine Sea plate, and crustal deformation of the Huatung Basin basement imaged on the seismic reflection profiles occurred either before or in the early stage of the arc-continent collision, leaving the overlying post-collisional sediments little affected.

T1-09

FOREARC GROWTH AND BASIN COLLAPSE IN THE TAIWAN COLLISION

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Three geophysical transects, based on the TAICRUST onshore-offshore seismic experiment around southern Taiwan, are used to examine the spatial and temporal development of the forearc in a region of incipient arc-continent collision. The southernmost transect shows that the submarine accretionary prism grows by a combination of sediment offscraping along the frontal thrust and underplating, in the form of duplexes, beneath the lower trench slope. Seamounts may be partially accreted to the base of the prism beneath the upper trench slope. The rear of the prism is the site of blind backthrusting on the order of 1-2 km above a trenchward-dipping backstop composed of island arc crust. The prism increases in width and thickness in the region of incipient collision as the frontal thrust propagates westward through sediments derived from the Taiwan orogen and downward into post-rift and syn-rift strata of the Chinese continental margin. Stretched continental crust subducts eastward beneath a thick, subaerially exposed accretionary prism, which is also underthrust along its rear by island arc crust as plate convergence is partitioned throughout the forearc region. Thickening of underthrusted sediment layers and within the crust of the subducting Eurasian plate in this region suggests crustal duplex formation and underplating of these packages beneath the Hengchun peninsula. Alternatively, the thick crust beneath the peninsula may represent deformation associated with the interaction of transitional crust in the subducting plate and an upturned edge of island arc crust of the Philippine Sea plate.

T1-10

WEST-VERGENT FOLD-AND-THRUST BELT IN THE FRONT OF THE HIDAKA COLLISION ZONE, HOKKAIDO, JAPAN

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A fold-and-thrust belt has been growing west of he Hidaka Collision Zone (HCZ , Cf: Ito et al.'s paper in this symposium) since the initiation of the collision between the Kuril and the Northeast Japanese arcs. The active front of the belt has migrated westward, now reaching Tomakomai several tens of km west of the HCZ. The accumulation of both seismic reflection and geological data makes it possible to (1)decipher the subsurface structure of the fold-and-thrust belt, and (2)reconstruct the collisional history between the two arcs. The master detachment of the belt originates from the delamination-wedge structure beneath HCZ, becoming a frontal blind thrust beneath Tomakomai.

T1-11

MARINE SEISMIC PROFILING ACROSS THE BEPPU BAY, NORTHEASTERN EXTREME OF THE BEPPU-SHIMABARA GRABEN, SOUTHWEST JAPAN

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The Beppu-Shimabara Graben running across Kyushu island constitutes a very rare example in the Japanese islands of active extensional tectonics with both high volcanism and active seismicity. Futhermore, the graben is located in a geologically complex region, and its origin and history are still controversial. Moreover, thick pyroclastics filling the graben have made it difficult to resolve the controversies. Therefore we conducted a marine seismic profiling project across Beppu Bay, the northeastern extreme of the graben. The results indicate: (1) The southern border of the graben is formed by a gently N-dipping listric fault, which becomes subhorizontal at about 5 km deep. In contrast, a distinct northern border does not exist. (2) The hanging wall has been moving in a normal sense with a right-lateral component. (3) A distinct reflector at 8 km depth may correspond to the top of a magma chamber beneath the graben. These observations provide important new constraints on the tectonic problems related to the graben.

T1-12

ACCRETION DEVELOPMENT STRUCTURE BENEATH KYUSHU ISLAND, JAPAN, DEDUCED FROM A SEISMIC REFRACTION AND WIDE ANGLE REFLECTION EXPERIMENT

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A seismic refraction and wide angle reflection experiment was executed in Kyushu island, western Japan. The profile crosses five geologic belts, from north to south, they are Cretaceous Sangun Massif, Ryoke, Sanbagawa and Chichibu metamorphic belts, and Tertiary accretion Shimant belt. The experiment consists of 6 shots and 236 observation sites with length of 228 km. Record sections show remarkable changes in travel-times and attenuation of amplitudes. The final crustal model which was obtained by ray-trace forward modeling analysis, have complicated boundaries. Sedimentary layers with velocities 3.5-4.3 km/s are developed in southern part of profile. Beneath the sedimentary layer, a basement layer with velocities 5.3-5.8 km/s is found. Crystalline granitic layer with velocity of 5.9 km/s have rugged upper boundary changing its depth from 2 to 12 km. Beneath Shimant belt at 100 km and 180 km from north of the profile, the upper boundary of crystalline granitic layer is very steep in south direction but gradual in north direction, suggesting existence of two large reverse fault which maybe caused by accretion process. Some groups of reflection phases were useful to detect mid crustal boundaries and the Moho. However, strong attenuation prevents precise analyses of deep structure.

T1-13

TOWARD UNDERSTANDING OF SUBDUCTION EARTHQUAKES: JAMSTEC SEISMIC STUDY IN SEISMOGENIC ZONES -

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Subduction zones produce the largest and potentially the most destructive earthquake on the Earth. Even if understanding of the subduction earthquakes are scientifically and socially important, little would be known about the seismogenic zone where large thrust earthquakes occur (e.g. deep and fine structure between forearc crust and oceanic crust, factors to control the updip and downdip limit of the seismogenic zone, temporal relation between stress-strain and the earthquake cycle). Japan Marine Science and Technology Center (JAMSTEC) has started a new research program, named Frontier Research Program for Subduction Dynamics, in order to examine and reveal the mechanism of subduction zone earthquakes mainly around Japan. One of the main approach is a MCS-OBS lithospheric study. We have already made seismic studies at the Nankai Trough, SW Japan, and the Japan Trench, NE Japan, in 1997 and 1998. An integrated seismic study, including conventional MCS study, 2 ship wide-angle study and OBS wide angle study using closely (< 2 km spacing) deployed OBSs, are planed in the Nankai Trough in 1999. In this paper, we present deep seismic images we have obtained in the Japanese seismogenic zone, and also show the future research plane of JAMSTEC seismic study.

T1-14

DEEP TO SHALLOW SEISMIC REFLECTION PROFILING ACROSS THE ACTIVE SENYA FAULT, NORTHERN HONSHU, JAPAN

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The Senya fault is a typical active thrust in northern Honshu Japan and generated the 1896 Riku-u Earthquake (M7.2). The deep and shallow seismic reflection profiling across the Senya fault, was undertaken to reveal the continuous geometry from deep seismogenic fault to shallow active fault. Along the 25-km-long seismic line, deep seismic profiling was performed using four Vibroseis trucks and 30-500 kg dynamite at about 5 km intervals. High resolution shallow seismic reflection profiling also revealed the frontal structure of the Senya fault. Both result provides the detailed structure of the Senya fault in the upper crust. The probable extension of Senya fault merges to a horizontal mid-crustal detachment at depth of 12-15 km, and shows listric geometry dipping from 30-50 degrees in the upper crust. At depth of 1 km, it has a detachment again in Tertiary mudstone and becomes emergent thrust dipping 30 degrees. In Northern Honshu, thin-skinned tectonics is applicable for the deformation of late-Tertiary sedimentary rocks. Low angle detachment fault commonly accommodates in the Miocene mudstone deposited post back-arc opening stage. Deep seismogenic fault shows relatively simple geometry in the upper crust and strongly controlled by inversion tectonics; Miocene normal fault reactivated as reverse fault.

T1-15

CRUSTAL STRUCTURE ACROSS THE NORTHERN HONSHU ARC, JAPAN, AS REVEALED FROM A WIDE-ANGLE SEISMIC EXPERIMENT

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An extensive wide-angle seismic experiment was conducted in the Northern Honshu Island, Japan, in October 1997, to elucidate a detailed crustal structure of the volcanic arc and its lateral heterogeneity. On E-W profile line of 150-km length, 293 recording units were deployed with a spacing of 0.5 km, and 6 large (500 kg-charge) and 4 middle (100 kg-charge) shots were detonated. These land stations also recorded 2 marine shots detonated on the westward extension of our profile in the sea of Japan.The obtained data indicated a remarkable lateral variation in the crustal structure. In the eastern part of the Honshu Arc, the crust is characterized by a 5.9-6.0 km/s crystalline basement and reflective middle/lower crust. Travel time data on the western part of the profile show significant undulation, probably representing the Cenozoic crustal deformation in the process of the back-arc spreading and the following compressional stress regime in the surveyed region.

T1-16

DEEP STRUCTURE AROUND AN EARTHQUAKE SWARM AREA, MIYAGI PREFECTURE, NORTHEASTERN JAPAN

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We conducted deep seismic profiling experiments in the southern Kitakami area, Miyagi prefecture, northeastern Japan. This area is one of the most active earthquake swarm areas in the northeastern Japan, which is known as the focal area of the hazard earthquke "1962 Northern Miyagi Earthquake (M6.5)". The hypocenters of these microearthquakes are distributed on a plane dipping to the west-northwest at an angle of about 50°. Recently a SxS-reflector has been found beneath the hypocenters. Parameters of data acquisition are as follows: totally 23 km-long seismic lines, 39 shot points in the average interval of 600 m, 20-30 kg explosives per a shot point, 940 receiver groups at the interval of 25 m, record length of 30 s at the sampling rate of 4 ms. Our seismic data revealed the first clear evidence of so-called "reflective lower crust" in Japan. The reflective lower crust is remarkable to the east of the earthquake swarm area, while it is vague beneath the earthquake swarm area. Also we found two deeper reflectors around 70 km in depth, which indicate the surface structure of the descending Pacific Plate. These reflectors may correspond to the oceanic crust of the Pacific Plate brought into the mantle beneath Japan.

T1-17

THE SOUTHERMOST CHILEAN MARGIN: INSIGHTS FROM PRE-STACK DEPTH MIGRATION AND 2D GRAVITY MODELING

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The Chilean convergent margin south of the Strait of Magellan represents an excellent opportunity to study a style of subduction where most of the parameters controlling this process remain constant except one: obliquity. The area of study lies on this margin between 52°S and 57°S. Three major tectonics events have shaped the evolution of this region: 1) the development and destruction of a back-arc basin between Late Jurassic to Mid Cretaceous times, 2) the opening of the Drake passage and the separation of the Antartic Peninsula from South America beginning about 30 Ma, and 3) the Chile Rise - Chile Trench collision at about 14 Ma. Since then, the Chile triple junction defined by this collision (Nazca - Antartica - South America) has moved rapidly northward along the margin to its present position at about 46°S near the Taitao Peninsula. In February of 1988 multichannel seismic (MCS), gravity and magnetic data was collected in the study area by the Lamont-Doherty Earth Observatory during R/V R. D. CONRAD's MCS cruise C2902. Pre-stack depth migration and 2D gravity modeling has been applied to one of the MCS acquired lines (C2902-790). Pre-stack depth migration, unlike stacking, allows for the refraction of rays according to Snell's law and creates a depth section wich contains true geometries and an accurate velocity model. Three main domains are imaged from SW to NE, a) the oceanic domain, where the Chilean trench is buried with a clastic sedimentary wedge of about 3 km of maximum thickness, b) the Fuegian Terrace domain, with an accretionary wedge, about 40 km wide, of highly deformed sediments with a clear Bottom Simulating Reflector (BSR) and a nearly undeformed forearc basin of about 25 km wide and a maximum sediment thickness of 4 km, and c) the continental domain wich consists of an 8° dip continental slope and the continental shelf.

T1-18

3D VELOCITY STRUCTURE ABOVE THE SUBDUCTING JUAN FERNANDEZ RIDGE OFFSHORE CENTRAL CHILE

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The Juan Fernandez aseismic ridge is subducting into the Chile Trench at a rate of ~100 mm/y between 32° and 33° S. Here the Valparaiso forearc basin lies opposite the subducting ridge at a midslope depth, one of only a few significant basins along the central Chilean margin. The region is also the site of large historical earthquakes and enhanced shallow seismicity relative to areas north and south along the margin. To investigate the influence of seamount subduction on the margin structure and its relationship to the local seismicity pattern, 3D seismic wide-angle data were collected during the cruise of RV Sonne 103 in 1995. Both in-line and off-line data were acquired with ocean bottom hydrophones using a network of 10 intersecting profiles. The data constrain the velocity structure over a 85-85 km region to ~15 km depth, including the continental upper crust and the top of the subducting oceanic plate. We present the results of applying traveltime inversion using a 3D tomographic method incorporating regularization. The 3D image shows several large-scale features such as the Valparaiso Basin, the forearc wedge, the Punta Salinas Ridge, and possibly the top of the subducted Papudo seamount

T1-19

THE EROSION SUBDUCTION PROCESS OFF NORTH CHILE DERIVED FROM *CINCA* GEOPHYSICAL AND GEOLOGICAL DATA

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In 1995 a comprehensive set of amhibic geoscientific data was acquired at the active continental margin off North Chile between 18° and 26° southern latitude by German, Chilean and Spanish research institutions: CINCA. Prevailingly on the basis of the marine MCS data in combination with off- and onshore seismic wide-angle/refraction data a model of tectonic subduction erosion could be developed that involves to a great deal gravitational mass transfer and removal from the upside of the continental slope. Tilted and rotated blocks have been identified at different depth levels along the continental wedge. The listric shape of normal faults and deeper reflector units clearly demonstrate an extensional regime deeply transsecting the wedge. High-resolution bathymetric data, wide-spread turbidites and the presence of slumps, strongly indicate gravitational effects and downslope mass transport toward the trench. At the foot of the slope a wedge-like unit of up to 2 km thickness with reduced seismic velocities and basically irregular reflection pattern was detected. We believe that this is the dumping site of all the down-slid rock material that subsequently is filled into the gaps of the oceanic crust that are provided by horst and graben formation on top of the oceanic crust by bending when approaching the trench. The open volume of the gaps is around 40 to 50 km³ per Ma and per km trench length. Mixed with broken oceanic rocks the debris is taken away in the subduction process similar to a conveyor belt. This implies a transition from the extensional regime of the shallower parts of the slope to a compressional one at its foot and at the subduction plane. About 30% of the eroding continent is assessed to be removed by this process and subducted with the downgoing slab.

T1-20

CRUSTAL STRUCTURE OF SOUTHERN MIDDLE AMERICAN LANDBRIDGE: NEW INSIGHTS FROM COMBINED SEISMIC PROFILING AND LOCAL EARTHQUAKES TOMOGRAPHY IN COSTA RICA

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A joined study of active and passive seismic data have provided new insights to constrain the velocity crustal structure across the Middle American Landbridge in Costa Rica. This study comprises data from airguns and terrestrial shots recorded at 10 OBH's and 60 portable landstations along an offshore-onshore profile of 260 km in northern Costa Rica, and from 583 well locatable local earthquakes recorded by 81 stations of Costa Rican seismic networks between 1991 and 1998. The onshore crustal structure derived from modeling of the seismic profile show a very thick crust (up to 40 km) with seismic velocities which are compatible with those expected for a fragment of continental crust. However, low amplitude PMP reflections makes weaker the velocity contrast between the lower crust and the upper mantle, resulting in a roughly Moho boundary estimate. Crustal velocities remarkably coincide with the outcome of simultaneous inversion of 1-D velocity model and hypocenter locations from local earthquakes. The inverted seismic velocity, between 40 and 60 km depth, is relatively low (7.4-7.5 km/s), which agrees with the seismic profiling results, providing strong evidences for the occurrence of underplating beneath the isthmus. These results, together with recent dating of outcropped igneous basement and according the tectonic evolution of the Caribbean Igneous Province, allow us to suggest that the Costa Rican landbridge is a continentalized crust fragment. We believe that this crustal development was produced by underplating of tholeitic material during the last 80 Ma beneath an oceanic island arc originated in the Late Cretaceous. The offshore crustal structure in northern Costa Rica is characterized by the subduction of a standard oceanic crust (6-7 km thick), with a dip angle of 25-30°. The velocity distribution within the marginal wedge suggests that it is basically an offshore extension of the Nicoya ophiolitic complex, instead of a typical accretionary prism. The simultaneous inversion of the 3-D velocity field and the hypocenter locations have allowed to locate several well resolved large scale velocity anomalies (> 25 km), and to better constrain the seismogenic zones.

T1-21

DEEP REFLECTION IMAGING AND DRILLING AT CONVERGENT MARGINS PERSIST IN DOCUMENTING SUBDUCTION-CAUSED EROSION OF UPPER PLATE LITHOSPHERE: NEW EXAMPLE FROM COSTA RICA AND THE BROADER IMPLICATIONS FOR INTERPRETING SEISMIC IMAGES OF ANCIENT OROGENIC BELTS AND ARCS

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Full-crustal seismic imaging, and recent coastal studies and ODP drilling of the convergent margin of Costa Rica, which connects the pre-Mesozoic continental crust of the Americas, appear to document rapid rates of subduction erosion during the past 20-25 my (i.e., 2-3 km of landward trench advance/my). Since the late Oligocene, an outboard sector of the margin at least 50-60-km wide has been removed and the material either underplated beneath onshore Costa Rica or recycled to the mantle. Similar results and implications have been reported from four well-imaged segments of the Chile margin (one drilled), and from the Tonga (drilled) and the Scotia (not drilled) subduction zones. By implication, the imaged architecture of the upper plate of an onshore orogenic belt is likely to reveal the seaward-truncated grain of its older or pre-collisional rift or arc fabric. By implication, Proterozoic and Archean continental reconstructions must depend upon success in re-connecting a rock and structural framework abridged (foreshortened) increasingly with time by cycles of subduction erosion, each potentially involving hundreds of km of crustal truncation. The Pacific margin of most of South America is a modern or Meso-Cenozoic example of severe cratonal truncation.

T1-22

STRUCTURE OF THE CONTINENTAL CONVERGENT PACIFIC MARGIN OF NICARAGUA

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Three reprocessed multichannel seismic reflection sections across the offshore part of the Pacific Margin of Nicaragua comprise a cross section about 140 km long. The cross section traverses the Sandino Forearc Basin from near the shoreline to the middle continental slope. Seawards, the data show a small accretionary prism at the base of the landward slope of the Middle America Trench and beyond is the rugged topography of the oceanic subducting plate. In addition to standard processing, we obtained depth sections through iterative pre-stack depth migration. The result is an accurate depth section to about 9 km depth. We have mapped the seismic basement and define 6 seismic stratigraphy units in the fill, based on structure of the strata, their seismic character and velocity information. Two wells provide ages of the main seismically defined units. Detail velocity information obtained from focusing analysis can be used as an indicator of possible lithology. The forearc Sandino Basin depocenter is more than 9 km deep near the coast line. It contains sediment from Eocene (or upper Cretaceous?) to recent. A major event in the tectonic history of the basin was uplift of the 30 km wide tract that currently forms the edge of the continental platform. Major uplift was between early Eocene and Oligocene time. In the center of the forearc Sandino Basin folding and faulting display a growth history since pre-Eocene time. The major phase of compression in the forearc basin was during early-middle Miocene, coeval with the collision of the Central and South American plates. Pervasive normal faulting and slight doming of the strata overlying the outer basement high indicates local ongoing uplift. This area is located above the seismogenic zone, where coupling along the plate boundary is strong. This indicate that the uplift and normal faulting are a response of the upper plate to stresses building in the area of coupling. Alternatively, the uplift and normal faulting could be caused by underplating at the base of the upper plate of sediment that bypasses the small frontal prism.

T1-23

CRUSTAL EVOLUTION FROM THE SOUTHERN MARGIN OF BAJA CALIFORNIA PENINSULA TO THE JALISCO BLOCK (WEST MEXICO)

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The achievement of a geophysical transect, during the CORTES-96 project, along more than 300 km from Puerto Vallarta to Los Cabos (southern tip of Baja California) yield new views of the lateral crustal variation from accretion at the East Pacific Rise (22°N) till the contact with the continental basement of the Rivera and Pacific Plates. Multichannel seismic profiles, swath bathymetry, gravity and magnetics data were acquired along this transect. Moreover, wide-angle and refraction seismic profiles recorded in 5 OBS, at both sides of the EPR, are completed with few landstattions placed at the south of Baja California peninsula and at the Tres Marías Islands. This configuration including gravity information allow to constrain the velocity crustal structure across the EPR and at the contact between the oceanic and continental crustal domains. The eastern most magnetic anomaly identified in the area is the anomaly 2A (3.5 Ma), placed near the Maria Magdalena Rise (MMR). All along the MCS profile the sedimentation is scarce and never exceeds 700 m in agreement with this young crust and with a low sedimentation rate. In particular close to the MMR the low sedimentation rate together with a high reflectivity displayed in the backscatter records suggest an oceanic type of crust, instead of continental one as proposed by many authors. Thus the oceanic continental boundary should be placed more to the east (i.e closer to the Mexico mainland). The integration of the different data along the transect defines the crustal architecture at the contact between the crust generated at the EPR and the crust at the Pacific and Rivera-North America plates.

T1-24

THE CONTINENTAL MARGIN OFF OREGON FROM SEISMIC INVESTIGATIONS

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Offshore Oregon, the Juan de Fuca Plate is subducting under the North American continent. In contrast to most subduction zones, no large earthquakes have been recorded along Cascadia's interplate boundary. However, geologic observations support the notion that catastrophic subduction zone earthquakes have nucleated here. To develop a model of the crustal structure, a geophysical study of the margin was carried out aboard RV SONNE in 1996. This cooperative experiment (known as ORWELL for "Oregon and Washington ExpLoration of the Lithosphere) of GEOMAR, the USGS and COAS involved the collection of wide angle seismic data along the margin off Oregon, using ocean bottom seismometers (OBS) and hydrophones(OBH) as well as land recorders. The EW dip line (profile 7) was chosen coincident with one of the multichannel reflection (MCS) lines that were shot for a university consortium by Digicon aboard the M/V GEOTIDE in 1989. Modeling of profile 7 shows a well imaged oceanic crust seaward of the margin. For modeling the accretionary complex, constraints from the MCS data were incorporated. West of the first ridge of the accretionary complex a proto-thrust zone is evident. Here, relatively high velocities are observed in the sediment. Previously accreted sediment shows reduced velocities in corresponding layers just above the decollement. We speculate that this velocity reduction is associated with development of the gas hydrate and underlying free gas system which is a common feature of accretionary complexes. The dip-angle of the subducting Juan de Fuca Plate beneath the margin, constrained by two strike profiles as well as by profile 7, is greater than 5°. Beneath the continental shelf, the velocity of material overlying the Juan de Fuca Plate at depths is greater than 4.8 km/s, reflecting the presence of the Siletz Terrane. Pronounced undulations in the overlying velocity contours reflect a system of margin-parallel basins. Current modeling efforts are focussed on delineating the boundary of the Siletz Terrane to test a model, based on magnetic anomalies, that shows a buried basement ridge to the west of this terrane, which might be an asperity inhibiting subduction.

T1-25

REFLECTIONS FROM A DEEP RIGHT-LATERAL STRIKE-SLIP FAULT ZONE

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In 1995 the U.S. Geological Survey detonated several large chemical explosions on San Francisco Peninsula in California in the San Andreas Fault Zone. The sources were generated to calibrate a 3-D seismic network, but were also recorded on a short (~10 km long) reflection spread oriented normal to the San Andreas Fault. Among the features of the data were late-arriving (11-13 s), relatively high-amplitude (~5 dB above background) reflections. These post-Moho events dip down to the southwest and come from out of the recording plane, reflecting from a southwest-dipping horizon located northeast of the recording array. The travel times of the 11-13 s events are consistent with either middle-crustal S-wave reflections, P-wave reflections from a shallow-dipping upper mantle horizon beneath San Francisco Bay, or a higher-angle horizon beneath the Hayward fault, a major strike-slip fault in the plate boundary zone that has accomodated 50-100 km of right-slip. The lack of middle crustal P-wave reflections that should correspond to 11-13 s S-wave reflections, and a further lack of upper mantle reflections on high-quality marine multichannel data from San Francisco Bay led me to focus on the Hayward fault zone as a potential reflector. A close fit was made to in-line and fan-geometry shot gathers by applying a 3-D tomographic velocity model and calculating reflection traveltimes to a 3-D, 70° dipping lower-crustal Hayward fault model.

T1-26

BASIX III: REFLECTION DATA INTERPRETATIONS FROM THE 1997 SAN FRANCISCO BAY AREA SEISMIC IMAGING EXPERIMENT

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The U.S. Geological Survey has conducted three Bay Area Seismic Imaging eXperiments to acquire deep-crustal seismic reflection data across the San Andreas Fault zone in north-central California, U.S.A. Shallow-water data acquisition methods were used to take advantage of the inland waterways of the San Andreas Bay area. The goals of BASIX are to better understand the regional three-dimensional crustal structure and how strain is distributed among the area's major right-lateral strike-slip faults.Data from BASIX-I (1991) and BASIX-II (1995) show a zone of reflectivity beneath central and southern San Francisco Bay between 6 to 8 s two-way travel-time. This reflective zone was interpreted as a possible 15 to 24 km deep sub-horizontal detachment linking the San Andreas and Hayward faults. Ray-trace modeling showed that the reflections could be explained as out-of-plane events from steeply-dipping interfaces but data coverage and geometry were not sufficient to distinguish between these interpretations. BASIX-III, conducted in September 1997, was designed to address the question of high-angle origin for these reflections and their lateral extent. Data acquisition was limited by the geographic constrains of the navigable Bay Area waterways. Two ships were used: an anchored recording vessel that deployed a 2.4 km hydrophone cable onto the bay floor at five separate locations and a shooting vessel that towed a 12-gun 96-liter air-gun array from vertical incidence to source-receiver offsets of up to 25 km. The high signal-to-noise data show no regionally continuous, horizontal reflector beneath San Francisco Bay. Modeling based on the reflectivity recorded between the San Andreas and Hayward faults indicates a dipping out-of-plane origin. No deep-crustal reflections were observed east of the Hayward fault.

T1-27

TECTONIC UNDERPLATING OF GORDA CRUST IN THE MENDOCINO TRIPLE JUNCTION REGION, NORTHERN CALIFORNIA

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An apparently ubiquitous high-velocity layer lies at the base of the crust beneath the Coast Ranges of central and northern California. Previous models for the origin of this layer invoke either basaltic underplate from upwelling asthenosphere following Gorda slab removal, or transport with the Pacific plate motion of tectonically emplaced oceanic crust along the San Andreas fault (SAF) system. Each of these models violates aspects of seismic observations along the margin (Hole et al., 1997). We use reflection and refraction seismic data from the 1993 and 1994 Mendocino Triple Junction (MTJ) Seismic Experiments to propose an alternate model for its origin. An east-west transect south of the MTJ shows that the lower crustal layer extends 100 km landward of SAF within 50 km of the southern edge of the Gorda slab, and is apparently cut through to the Moho by the San Andreas and related faults. Although the lower crust appears to be actively intruded, the small melt volumes present, the upper mantle P-wave seismic velocity of 8.0 km/s, and adiabatic calculation for melting of dry mantle suggest that the layer is not formed solely by in situ igneous underplating. An east-west transect north of the MTJ shows Franciscan accretionary terranes directly overlie subducting Gorda crust (Trehu et al., 1996). Two transects that cross the continental margin near Cape Mendocino show downward flexure of the Gorda crust and imbrication of the lower crust beneath the Vizcaino block consistent with tectonic models in which Pacific-Gorda interactions are dominated by compression across the Mendocino transform. We suggest that the relaxation of this compression as the Gorda slab passes east of the MTJ results in the separation of the Gorda crust from the upper mantle. The band of seismicity in the MTJ region parallel to but 5-10 km deeper than the Gorda Moho would allow most of the mantle slab to subduct while the Gorda oceanic crust and a thin layer of mantle material is tectonically underplated beneath the accretionary terranes.

T1-28

LITHOSPHERE RHEOLOGY AND THE FORMATION OF OCEANIC MEGAMULLIONS AND METAMORPHIC CORE COMPLEXES

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Tucholke et al. (1998) have recently related oceanic megamullions (OMM's) observed near ridge transform intersections at the Mid-Atlantic Ridge to continental metamorphic core complexes (MCC's) that form, among other places, in the Western U.S. Basin and Range Province. The similarity in scale of these structures is at first surprising because the tectonic environment in which they are inferred to have formed is so different. OMM's form in near zero age oceanic crust. MCC's, on the other hand, are thought to form in overthickened continental crust. I suggest that we can understand the similarity between these environments by looking at the strength profiles for the lithosphere in the two situations.The profile for oceanic lithosphere is most often constructed using an olivine rheology for both crust and upper mantle. The profile for continental crust is most often constructed using a granite rheology for the crust and olivine rheology for the upper mantle. Under the conditions for forming MCC's, thick crust and mildly elevated heat flow, the profile shows a crustal strong zone in the upper 8 or so km of the crust, a very weak lower crust, and no upper mantle strong zone. Under the conditions for OMM's in 1 my old crust with high heat flow, the profile shows an 8 km thick strong zone, encompassing the entire crust and the uppermost mantle. In terms of strength and strong layer thickness, the lithosphere in both cases is identical. That olivine is about 3 times stronger than granite in the ductile regime trades off with the 3 times higher heat flow near the mid-ocean ridge.

T1-29

A NEW VIEW OF THE GALICIA S REFLECTOR: *ISE-97* RESULTS

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Preliminary analyses of MCS and OBS data from the Iberia Seismic Experiment (ISE-97) suggest that the S-reflector, although definitely a low-angle fault surface, may not have been the single, primary, detachment controlling the rifting which formed the Galicia margin. Rather it appears that S is the last of a series of similar faults that stepped progressively westward and detached progressively thinner slices of extended continental crust. Each of these detachments is bounded to the east by a breakaway fault and to the west forms a structural Moho. Our data confirm that where S is well developed, it does seem to form the crust mantle boundary. The variation of the S-reflector surface also appears more complicated in the along-margin (north to south) direction than heretofore reported. There are a series of faults which begin at the S reflector and dip about 30° to the north penetrating 5-10 km into the upper mantle. In a few places, these faults appear to offset the S reflector in a normal sense. Where the faults intersect S, the reflection character of S often changes. The two later observations suggest that there was mantle involvement in the creation of the S reflector.

T1-30

2D AND 3D VELOCITY STRUCTURE OF THE IBERIA MARGIN FROM THE INVERSION OF WIDE-ANGLE TRAVELTIME DATA

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The 1997 Iberia Seismic Experiment (ISE97) acquired wide-angle and multichannel data on the Iberia margin over a 340x280 km area. The coincident MCS data are presented in a companion poster by Sawyer et al. The wide-angle data constrain the 2D crustal and uppermost mantle velocity structure beneath the Galicia Interior Basin, Galicia Bank, and the transform boundary with the Iberia Abyssal Plain. The data also constrain the 3D structure in a 35x35 km region where the S reflector is best observed in the MCS data, apparently forming the base of a set of faulted and tilted basement blocks. 25 ocean bottom instruments from Geomar and the University of Texas Institute of Geophysics were deployed along 3 strike lines and 3 dip lines 50 to 340 km in length, with instrument spacings of 5 to 30 km. Two-way traveltimes from the unmigrated MCS data were inverted along with the wide-angle data. The 2D velocity model for the longest dip line shows apparently normal oceanic crust at the west end of the profile, and extended continental crust with the Moho at 20 km depth near the coast. The S reflector at 8 to 9 km depth separates less than 2 km of typical crustal velocity rocks (6-6.6 km/s) above from rocks of at least 7.5 km/s velocity below.

T1-31

THE STRUCTURE OF THE GALICIA INTERIOR BASIN, WEST OF IBERIA

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The continental margin off the west Iberia is a non volcanic margin formed during the rifting between Iberia and New Foundland that led to the opening of the Atlantic. Offshore NW Iberia, between a narrow shelf and the Galicia Bank (GB), is the NS trending Galicia Interior Basin (GIB). Several episodes of rifting affected this failed rift from Triassic to Early Cretaceous (Valanginian) when the focus of extension moved west, to the west of GB, where the continental break-up occurred 25 m.y. later. To study the tectonic structure of this basin and the reasons for rift failure we have processed 4 multichannel seismic reflection profiles across the basin. Key points in data processing were: deconvolution (deterministic and statistical), multiple removal (by filtering in the FK domain and using wave equation method) and cascaded migration. The preliminary results of the geological interpretation of the data are: 1. the tectonic structure of the GIB is characteristic by tilted blocks bounded by landward dipping normal faults. This type of extension suggests the existence of a master fault beneath the continental platform. 2. To the west of the GB, faults dip seawards. The tectonics in this area are probably related to the final extensional episode, during early Cretaceous, that led to the continental break-up west of GB. 3. The small amount of extension inferred for this basin is questioned by the presence of low angle detachment faults and by the large amount of rotation observed at some tilted blocks. 4. We suggest the possibility of mantle unroofing in this basin, as that observed to the south west off the west Iberian continental margin.

T1-32

REFRACTION/WIDE ANGLE REFLECTION INVESTIGATION OF THE CADOMIAN CRUST BETWEEN NORTHERN BRITTANY AND THE CHANNEL ISLANDS

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In order to investigate the crustal structure of the North Armorican block, a combined GéoFrance3D and SISCAD seismic refraction experiment has been performed offshore Northern Britanny by means of numerous airguns shooting on board RV Nadir and recording both on ocean bottom seismometers and land stations. We present the 2D velocity models computed from two crossing seismic refraction profiles, labelled P1 and P2 about 135 km long each, which were oriented NE-SW and NNW-SSE, i.e. parallel and perpendicular to the regional basement structures. Wide-angles profiles were also performed to extend the 2D structures to a 3D crustal interpretation. Observed and calculated P-wave traveltimes were matched by forward modeling prior their inversion in order to produce two crustal velocity models.

T1-33

EXHUMED MANTLE AT THE OCEAN-CONTINENTAL TRANSITION IN THE SOUTHERN IBERIA ABYSSAL PLAIN

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At "non-volcanic" rifted margins, where synrift igneous activity is limited or absent prior to the onset of seafloor spreading, it is commonly speculated that a broad ocean-continent transition zone (OCT) exists between the most seaward continental fault blocks and the most landward seafloor spreading magnetic anomalies. The structure of the OCT provides important constraints on the processes which occur as distributed continental extension becomes focused at a spreading centre. We present results from a seismic and magnetic study of acoustic basement beneath the southern Iberia Abyssal Plain. Here, the OCT is characterised by subdued basement relief and weak magnetisation, which contrast with isochron-parallel basement ridges and higher magnetisation further west. The width of the OCT decreases to the north. High velocities at shallow depths within acoustic basement and other evidence suggest that the OCT consists largely of serpentinised peridotite. A network of seismic reflection profiles around the ODP Legs 149 and 173 drill sites provide additional constraints on their tectonic setting. Our magnetic and seismic data support the hypothesis of exhumed upper mantle, more than that of ultraslow seafloor spreading, for the origin of the OCT.

T1-34

DEEP CRUSTAL STRUCTURE AND SEISMICITY FROM THE GALICIA INTERIOR BASIN TO THE HERCYNIAN MASSIF. *ESIGAL-97* PROJECT

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During July and August 1997 a large deep seismic experiment and a seismicity investigations was carried out at the NW of the Iberian Peninsula and territorial waters. The R/V Maurice Ewing provided a source energy consisting of an airgun array of 20 guns with a total capacity of 8385 c.i. The powerful seismic signal generated by the vessel allowed to acquire high quality seismic records up to 400 km distance from the West coast of Galicia. We deployed 25 portable landstations, from the coast till Galicia mainland, distributed in two E-W profiles covering a total length of 150 km each one. These two lines were prolonged seaward for more than 150 km and recorded by 10 OBS-OBHS. Moreover, a permanent seismic network was installed in the area of Lugo-Becerreá-Sarria, to listening simultaneously the seismicity of the region and the airgun shots. This station distribution allowed to well control the transition zone between the oceanic and continental domains. The continental domain is characterized by outcrops of the Iberian Massif and the oceanic domain is made of different rotated blocks that furnish useful information about the crustal structure prior to the opening of the Atlantic ocean. In this broad and complex area, for the first time we have studied the deep crustal structure of the Galicia Interior Basin (GIB) and its transition to the continent, with an excellent seismic coverage of the refracted and reflected phases. The Moho depth is controlled by a high amplitude PmP reflection phase, which in addition gives information of the geometry of a significant crustal thinning (10 km within 100 km distance) from the Galicia Hercynian crust toward the GIB. The data are well constrained by a rigorous control of the Vp velocity in the upper mantle.

T1-35

SEISMIC AND GRAVITY STRUCTURE OF ATLANTIC IBERIAN MARGINS: GALICIA, HORSESHOE ABYSSAL PLAIN AND GULF OF CADIZ

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The seismic structure of three areas of the Atlantic Iberian has been investigated by means of densely sampled (75 m) refraction/wide angle reflection seismic information, recorded simultaneously with deep near-vertical seismic reflection data and combined with gravity modeling. Seismic data was obtained during the IAM (Iberian Atlantic Margins) experiment, carried out in 1993. The energy of the 0.123 m3 (7524 cu.in.) air gun array, with a pop-rate of 30 s was recorded by a 4.8 km streamer offshore and by portable seismic instruments onshore. In the Gulf of Cadiz, 4 seismic profiles were carried out. Our results indicate a continental type crust in the entire Gulf of Cadiz, with progressive thinning from East (27 km at 6° 30' W) to the West (20 km at 90° W). The sedimentary cover shows a great thickness, reaching 8 km in the central part of the Gulf of Cadiz. In a N-S direction, the thinning of the continental crust is more pronounced, from 30 km below the shoreline to 25 km at 50 km offshore. The results of the present work provide a detailed crustal model that heavily constrains previous results obtained onshore from low density wide angle data. From the southwestern part of the Iberian Peninsula to the Horseshoe Abyssal Plain, a 200 km long profile shows the thinning of the crust from the non-rifted Iberian Massif, with a thickness of 29 km under the shoreline, to a thickness of 15 km at a distance of 80 km to the shoreline. In the Galicia margin, an E-W profile, 400 km long, was carried out from the ocean-continental boundary (OCB) to the non-rifted Iberian Massif. This profile shows two thinned areas of the crust, corresponding to the Deep Galicia Margin (the rifted continental margin) and the Galicia Interior Basin (GIB) (a probably abandoned rift basin). We interpret a variation of the crustal thickness from 31 km onshore to 19 km below the GIB and from 22 km below the Galicia Bank to 9.5 km near to the OCB.

T1-36

CRUSTAL VIEWS OF THE GORRINGE BANK REGION AND GULF OF CADIZ: THE *IAM PROJECT*

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In 1993 the IAM Group collected near vertical incidence seismic reflection data over a total distance of 3500 km along the North and Western Iberian Margins, Gorringe Bank Region and Gulf of Cadiz. These data was complemented by land station recording of wide-angle and refraction data along many of the profiles. Here we concentrate on the results of the crustal structure of the Gorringe Bank Region and Gulf of Cadiz. The study area is located at the eastern end of the Azores-Gibraltar fracture zone, which is considered as the boundary between the Eurasian and African Plates. Results of reprocessing and interpretation of MCS data show that the crust of the GBR is of oceanic type whereas in the GC is of continental nature. North of the GBR (in the Tagus Abyssal Plain) recent deformation is restricted to narrow linear zones associated with major bathymetric features. In this area the Gorringe Bank Ridge is upthrusted against the TAP by a system of high angle faults which are responsible for the offsets of the oceanic basement and Moho observed along its flanks. To the south of the GBR, the Horseshoe Abyssal Plain is characterized by a variable thick sedimentary cover with maximum thickness in the central parts of the plain, including the presence of a variable thick layer characterized by its chaotic seismic reflection pattern. In this area, the Moho lies at about 11s twt. In the GC, the crust is of about 30 km thick along the continental shelf thinning to as much as 20 km in the central parts of the area.

T1-37

SEISMIC CONFIGURATION OF THE BETIC-ALBORAN OROGEN IN N-S AND E-W TRANSECTS

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At the southwestern tip of the Mediterranean, the plate boundary between European-Iberian and African plates occurs within continental lithosphere, where active right-lateral transpression is occurring due to the oblique convergence between Africa and Iberia. The relative motion between plates has been accommodated since the Neogene by diffuse deformation on a large number of structures distributed over a wide area that resulted in an orogen comprised of the Alboran marine basin flanked to the north and south by the Betic Cordillera in the South of Spain and the Rif-Tell Cordillera in the North of Africa. The crustal architecture of the northern half of this orogen has been investigated by ESCI deep seismic surveys in two transects, one N-S through the Betics onland to the center of Alboran sea and another E-W across the Eastern half of the Alboran basin. The most striking characteristic of the seismic profiles is the heterogeneity in the vertical and horizontal distribution of the reflectivity that configure a framework of panels with contrasting seismic pattern. The integration of geological data into the interpretation of the seismic profiles, in particular, the kinematics of major structures together with the well known structural styles of the units sampled by the profiles, allows us to propose that the northern half of the orogen is comprised of 4 major crustal elements within which the deformation is partitioned. Each crustal element is characteristic by the particular seismic pattern that correlates with a particular structural style, and is bound/joined with other elements by major tectonic contacts that transfer the deformation in the horizontal and vertical directions. The proposed 3-D orogenic architecture may explain the three-dimensional mode of deformation in the area of the plate boundary where the intracontinental shortening and transpression, was accommodated by orogen-parallel extension-extrusion and outboard thin-skinned contractional deformation.

T1-38

SEISMIC STRUCTURE AND THE ACTIVE HELLENIC SUBDUCTION IN THE IONIAN ZONE

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In the region of the Ionian islands off western Greece, the active margin of the Aegean domain passes from oceanic subduction in the south to continental collision to the north, by the link of the right-lateral Cephalonia transform fault. A first reflection line from the Ionian basin through the channel between Cephalonia and Zante islands (Hirn et al., Tectonophysics, 1997) revealed, among other features, energy at about 6 s TWT, which we interpreted as indicating a true reflector at depth. During the SEISGRECE cruise of N/O Le Nadir in 1997 additional reflection profiles were shot, one offshore Zante parallel to and 20 km south of the original profile, and another line perpendicular to the previous, extending the sampling into the basin south of Zante. A coherent reflection can be traced over the whole processed sections, continuously between places where it was clear already on the single channel monitor. The systematic existence of this reflection over a broad region and in diverse conditions of water depths and multiples establishes the reality of a regional structural interface. We interpret it tentatively as the interplate: thrust surface of the western Hellenides on the Ionian basin crust or pre-Apulian margin. Local earthquakes could be observed with a temporary but dense array of both OBS and land-based three-component seismometers, providing good depth control and constraints on mechanisms of earthquake sources, which projected on the reflection sections concur to this interpretation of the regional reflector, which topography is related to regional geodynamics.

T1-39

SEISMIC INVESTIGATIONS OF THE MAKRAN ACCRETIONARY WEDGE

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In September 1997, we collected a grid of marine seismic wide-angle profiles on the Makran accretionary wedge to study its internal structure. This data set contributes to a series of geoscientific investigations on the Makran shelf that will help to understand the structures and processes involved on a broader scale. Within this scope a 160 km long dipline was surveyed SE of Gwadar peninsula coinciding with an MCS line collected earlier by Cambridge University in 1986. Besides the integration of structural and velocity data, the combination of MCS and wide-angle data is an effective way to estimate the potential fluid loss of the sediment during accretion- subduction. Four additional wide-angle strike lines across this profile enable us to present a detailed model of the crustal structure. Makran is one of the largest accretionary wedges around the globe, a result of the convergence between the Eurasian and the Arabian Plates. Up to seven km of sediment has been deposited in the Gulf of Oman, comprising a lower unit of Himalayan turbidites, that are unconformably overlain by an upper unit of Makran sands. The shallow dipping subduction zone exhibits only few, but strong earthquakes along the plate boundary. Preliminary interpretation of the wide-angle data indicates that a décollement, as evidenced by a low velocity zone, is developed within the turbiditic sequence along a bright reflector. Up to three km of sediment is by passing the frist accretionary ridges and thus potentially a large volume of fluids is brought to greater depth, which might explain the sparse earthquake activity.

THEME 2: Integrated multidisciplinary studies

T2-01

CRUSTAL REFLECTION-REFRACTION PROFILE OF THE BYRD SUBGLACIAL BASIN, ANTARTICA

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A densely-recorded crustal-scale seismic refraction/wide-angle-reflection experiment was undertaken near the southern edge of the Byrd Subglacial Basin, Antarctica. The program comprised a series of wave tests to ascertain optimum shooting and recording parameters ice sheet, followed by the completion of a reversed 235-km-long profile. Ninety digital seismographs recorded 3-channel data from 3-component 4.5-Hz seismometers. A total shots varying between 12.5 and 3200 kg were detonated into three different seismo arrangements with a maximum offset of 218 km. The profile showed the bottom third of the ~30-km-thick crust to be highly reflective. Wave velocities near the top of the crust were 5.7 km/s, increasing to 6.1 km/s at about 9 km depth. The velocity of the lower crust (~22-30 km) varied between 6.5 and 6.8 km/s, although these velocities are not as well constraint as those above or below. Clearly identified forward and reverse refractions through the mantle indicate a true velocity of about 8.0 km/s. The crustal thickness and reflective lower strongly suggest extension, but the upper mantle velocity suggests extension is not currently active, at least in the area of the profile.

T2-02

GEOPHYSICAL INVESTIGATION OF A MODERN CONTINENTAL TRANSPRESSIONAL OROGEN: SOUTHERN ALPS, NEW ZEALAND

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The Indo-Australian - Pacific plate boundary in the South Island of New Zealand is characterized by active continent-continent transpressional collision. The associated Southern Alps orogen exhibits high uplift rates and rapid transcurrent movement. A joint US-NZ geophysical investigation of this plate boundary includes disciplines of seismic reflection, explosion refraction, onshore-offshore wide-angle reflection/refraction, regional and teleseismic passive seismology, magnetotellurics, laboratory petrophysics, gravity, and regional geological investigations. Principal findings so far include: (1) A rapid asymmetric thickening of the crust beneath and just east of the Indo-Australian/Pacificplate boundary (the Alpine Fault). At the west coast of the SouthIsland (I-A plate) the crust is ~27 km thick yet 40 km inland it is a maximum of ~46 km (Pacific plate). (2) The plate boundary can be traced to a depth of approx. 30 km as an eastward-dipping (approx. 40°) Alpine Fault Zone (AFZ) that is 10-15 km thick. The AFZ is seismically quiet, has low seismic velocities and below 20 km has resistivities as low as 30 ohm-m. (3) Teleseismic P-wave delays recorded across the South Island suggest subjacent high velocities in the mantle and a small but distinct low-velocity region in the AFZ. -Upper mantle shear-wave splitting is observed in the South Island and exhibits fast polarization orientation roughly parallel to the plate boundary.

T2-03

CRUSTAL STRUCTURE AND DEFORMATION OF THE EASTERN PROVINCE (MESOZOIC TERRANES), SOUTHEASTERN SOUTH ISLAND, NEW ZEALAND

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Seismic reflection and refraction data were recorded in 1996 along the southeast coast of South Island, New Zealand to study the crustal structure of a complex assemblage of terranes, Western Province and Eastern Province, which have been largely undeformed since Cretaceous times. The greater part of the transect (part of the SIGHT project) crosses Eastern Province terranes. Near-vertical multichannel seismic reflection (MCS) data were recorded to 16 s. The migrated stacks of 4 end-to-end lines provide an image of the crust to Moho. The main features of the MCS transect are: 1. A reflective sedimentary sequence varying in thickness along the transect. 2. Generally unreflective upper crust, except in the vicinity of Dunedin. Here, an upper to mid crustal reflective zone forms a crustal antiform with its apex near Dunedin, and corresponds to the change in metamorphic grade of the South Island greywackes and Otago schists 3. Reflective lower crust, with Moho lying at the base of the reflective zone at depths from 8 to 12 s TWT. The lower crust varies markedly in thickness and character along the transect. The refraction/wide-angle reflection data were analysed by travel time inversion, and the resulting velocity model was overlain on the MCS profile. The data show clear Pg and PmP arrivals out to the maximum range (130 km) and Pn detected to the maximum offset of the data (390 km). The upper and middle crust is about 20 km thick and has P-wave velocities of 5.5 - 6.5 km/s. The lower crust has velocities of 7.0 - 7.5 km/s and corresponds to the highly reflective lower crust observed on the MCS data. The transect crosses a number of terrane boundaries. The boundary between Eastern and Western Provinces is marked by a significant change in crustal thickness. 25 km thick crust of the Western Province is juxtaposed against 33 km thick crust of the Eastern Province Brook Street terrane. The complex crustal reflectivity and changes in thickness along this transect are associated with terrane amalgamation.

T2-04

NEAR-VERTICAL SEISMIC IMAGES OF A CONTINENTAL TRANS-PRESSIONAL PLATE BOUNDARY: SOUTHERN ALPS, NEW ZEALAND

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The crustal structure of the Indo-Australian/Pacific transpressional plate boundary in central South Island of New Zealand has been investigated in 3 separate near-vertical seismic reflection experiments of differing scale. In 1995 a pilot set of shots fired in Lake Pukaki near the Alpine fault identified strong crustal reflectors between 9-12 s twt which served as targets for subsequent profiling. Explosion gathers recorded during the 1996 SIGHT reflection/refraction create low-fold stacks transecting the South Island. The stacked and migrated images reveal a bright reflective zone up to 4 s thick whose top extends from 8 s (~24 km depth) and bends downward beneath the Southern Alps to 11 s (~30 km). Beneath this zone is the crustal root (45 km) coincident with the regional Bouguer gravity low (-100 mgal). A high-spatial resolution profile collected in 1998 near Mt Cook exhibits improved details of lower crustal reflectivity in the crustal root and possible reflections associated with the plate boundary. The polarity of the seismic signal at the top of the reflective zone is dominately reversed. Supporting evidence suggests that the fabric of this zone is caused by anisotropy: (1) It coincides with the base of seismicity and is likely to be a zone of concentrated shear. (2) It coincides with a zone of low conductivity interpreted from MT data. If rocks in the conductive zone contain fluid they are most likely the result of hydrous phases generated by metamorphic reactions. (3) Geobarometry of high-grade schist rocks exposed at the Alpine fault indicates depths of burial of between 19-25 km. (4) Petrophysical measurements on the same rocks give a maximum anisotropy of 17.3%.

T2-05

DEEP SEISMIC PROFILES ACROSS THE PACIFIC-AUSTRALIAN PLATE BOUNDARY, SOUTH ISLAND, NEW ZEALAND

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We present results from a comprehensive wide-angle and vertical-incidence seismic investigation of the Pacific-Australian plate boundary on the South Island of New Zealand. At this location, the Alpine Fault zone marks the surface trace of a continent-continent collision, which has built the Southern Alps mountain range, exhumed mid-crustal rocks, and produced deformation across a wide zone in the South Island. In the 1996 SIGHT experiment, we conducted an onshore-offshore seismic experiment comprising explosion refraction data, marine multichannel reflection data, ocean-bottom seismic data, and onshore-offshore wide-angle data. Data of exceptional quality were acquired across the plate boundary on two east-west transects; clear phases are observed out to source-receiver offsets of 250-300 km. Velocity models based on these data show an abrupt crustal thickness change of 15±5 km across the plate boundary, from 25-30 km thick crust in the Australian Plate to 40-45 km thick crust beneath the Southern Alps on the Pacific Plate. The plate boundary zone dips at 60±15 degrees to the east. Both plate appear to flex downward into the collision. Deep mantle reflections (up to 150 km depth) are detected beneath and west of the plate boundary, possibly suggesting a broad zone of shear in the mantle around the plate boundary. The Alpine Fault zone itself may produce a 10-km-wide low-velocity zone in the upper crust.

T2-06

DEEP SEISMIC IMAGING OF THE MT. TATEYAMA AND ITOIGAWA-SHIZUOKA TECTONIC LINE IN THE CENTRAL PART OF HONSU, JAPAN

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Fault reactivation and magmatic emplacement of the Earth's crust controlled deformation and/or formation processes of the island-arc crust. In the central part of the Japan, there are one of the major active faults, the Itoigawa-Shizuoka Tectonic Line (ISTL), and the Hida Mountains. The ISTL is an important geologic boundary that divides SW Japan and NE Japan. The ISTL also forms active fault system with a high averaged slip rate of a few mm/yr. We conducted a series of seismic experiments to understand the structure and dynamics of the island-arc crust. A seismic tomography study using local seismicity as passive sources in 1996 revealed a magma reservoir and a stagnated felsic magma beneath the Mt. Tateyama. We deployed 44 off-line 3-component 2-Hz seismographs and a local telemetered seismic networks to acquired seismic data. A 15-km reflection survey with four vibrator trucks conducted in 1997 revealed that the ISTL is east down-dipping reverse fault and Late Tertiary sediments are thrusting onto pre-Tertiary sedimentary rocks. The active tectonics of Honshu island is strongly affected by the structure formed during the back-arc spreading.

T2-07

NATURE OF THE SWALLOW REFLECTIVITY IN THE SG4 BOREHOLE AREA: CONSTRAINS ON THE STRUCTURE OF THE UPPER CRUST IN THE TAGIL SYNFORM (MIDDLE URALS)

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Vertical incidence seismic data (ESRU dataset) acquired in the SG4 borehole vicinity (Tagil Volcanic Arc, Middle Urals) show the upper crust to be highly reflective. Two seismic lines crossing ~2000 m WNW of the borehole (ESRU95) suggest that the source of the main reflectivity strikes ~NS and dips 35°- 50° to the east. Correlation between the surface seismics and the SG4 borehole geophysical data suggests that this reflectivity is related to low velocity/ density/resistivity zones. These zones intercept the 1500, 2900, 3400, ~4800-5200 m and often also correlate with lithological contacts, establishing a close relationship between lithological boundaries, reflectivity and the low velocity/density/resistivity zones. Constraints provided by P-S conversions in the VSP94-97 data suggest that the low velocity zones are primarily responsible for the reflectivity. The main source of reflectivity is therefore considered to be fluid filled mechanical contacts or fracture zones. N-S steeply west dipping events also appear in the vertical incidence data disrupting the east dipping reflectivity with an apparent extensional sense of movement. They have been interpreted as high-angle faults and, as yet, not observed on the VSP97 data. The structure of the Tagil Synform as shown by integration of borehole, vertical incidence and VSP data appears that of open synformal feature whose western limb is a thrust-related ramp anticline. Eastward it is overthrust by a west-vergent duplex, and is overprinted by late, steeply west dipping faults. The internal structure of the synform is complicated by oblique terminations of reflectors that are locally interpreted to be duplexes or unconformities. These features would locally repeat the sequences or produce the lateral variations of thickeness observed in the Tagil Synform.

T2-08

INTEGRATED MODELLING OF THE LITHOSFERIC STRUCTURE OF THE SOUTHERN URALS USING QUASIGEOID, GRAVITY, MAGNETIC AND SEISMIC DATA

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The URSEIS seismic experiment has provided exceptional images of the crust of the Southern Urals. Wide-angle seismic data identify a crustal root up to 55 km deep although the central part of the root is not clearly imaged in normal-incidence sections. In places, the latter have identified mantle reflectors at two way times of up to 55 s (equivalent to an apparent depth of c. 225 km). Models have been constructed for the crust beneath URSEIS which integrate gravity, magnetic and seismic data. To constrain deeper structure, and in particular the geometry of the lithosphere-asthenosphere boundary, variations in the quasigeoid have been modelled. Symmetric gravity and quasigeoid anomalies across the orogen indicate that the crustal root lies directly below the relatively dense Magnitogorsk Zone (island arc terrane). The models will not allow a lateral offset between the crustal load represented by this zone and the compensating root, although such a configuration has been implied by some interpretations based on the wide-angle seismic data. The forma of the quasigeoid anomaly admits the possibility of a lithospheric as well as crustal root. We cannot, on the basis of our initial models, rule out the possibility that the deeper reflectors relate to the lithosphere-asthenosphere boundary. In order to test these hypotheses more rigorously we are developing a program which allows interactive, simultaneous modelling of the gravitational and quasigeoid effect of lithospheric density structures.

T2-09

A MORE COMPLETE WIDE-ANGLE VELOCITY MODEL FOR THE NOTHERN PART OF THE BOTHNIAN BAY

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Wide-angle reflection-refraction digital data for lines 4,4A of 1989 BABEL survey are complemented with the record sections obtained from analog recording stations (BS1a, BS2) and new data from digital station F66. The main feature of the new model is the presence of north-dipping reflections in the middle crust (15-35 km) and a large undulation of the Moho boundary, ranging in depth from 47 km to almost 60 km, similar to observations from line 1. First arrivals with velocities above 7 km/s in the record sections of BS1a and BS2 indicate the presence of a thick layer with high velocity above Moho in the middle part of the profile BS2-F66, like that for the SVEKA profile. The new structural feature is possibly an evidence of a deep regional boundary, marked in reflectivity pattern. Selected sections of line 4,4A were used for evaluation of spatial coherency and scattering properties of P waves in the uppermost lithosphere.

T2-10

INTEGRATED WIDE-ANGLE SEISMIC AND GRAVITY INVERSION FOR CRUSTAL STRUCTURE BENEATH THE CENTRAL GRABEN, NORTH SEA

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An integrated seismic and gravity model is presented for the crust and uppermost mantle in a 315 km profile along east-west trending MONA LISA line 3 which crosses the Central Graben in the North Sea. The model is based on wide-angle seismic observations and gravity data and is consistent with coincident deep seismic normal incidence data. For the purposes of modelling, an integrated wide-angle seismic and gravity least squares iterative inverse approach has been used. By satisfying, simultaneously, seismic traveltimes, gravity observations as well as prior data given by a chosen velocity-density relation, an integrated velocity-density model is derived. The bonds given by the chosen velocity-density relation may be selected to be tight in regions of the model where the chosen velocity-density relation is expected to be trustworthy, and more relaxed in parts of the model where the velocity-density relation is believed to be less certain. The study profile crosses the Central Graben in a direction approximately perpendicular to the main strike direction of the graben system. Pronounced crustal thinning interpreted to be associated with lithospheric extension and graben formation is observed. Seismic data and stratigraphic information from well data indicate main subsidence to have occured during the post-Middle Jurassic extensional event. Beneath the up to 10 km thick sedimentary sequence of the deepest part of the Central Graben, the crystalline crust has been thinned to about 15 km thickness, and the Moho reaches its minimum depth of 25 km in this area. In adjacent basement highs, the Moho is interpreted to be situated at 32-34 km depth.

T2-11

INTERPRETATION OF THE SEISMIC AND RHEOLOGICAL DATA WITHIN AND IN FRONT OF THE EASTERN CARPATHIANS BEND AREA

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The Eastern Carpathians bend area (ECBA) has a complex tectonics: a series of folded and overthrust nappes of different ages and compositions override the Moesian Platform. ECBA is bordered to the East by the Focsani Depression (FD) that is the deepest Romanian depression and belongs the foredeep area. An important crustal and undercrustal seismicity is known within the both areas that in fact belong to the Vrancea seismic region. A E-W crustal seismic reflection line runs over the eastern flank of the FD. An westernward increasing of the thickness of the Miocene sediments along with the lack of crustal seismic reflectivity within the eastern half of the seismic line can be taken as evidences for a flexure of the lithosphere. A study on crustal anisotropy over an area that includes both the ECBA and FD is based on splitting shear waves having as sources more tens of undercrustal earthquakes from Vrancea region. The leading shear waves show a ?N300E polarization direction and the delay times between faster and slower split shear waves increase from the East (?0.21 s) to the West (?0.26 s). The anisotropy is due to a fracture system having a NE-SW strike and along which the platform descends under the FD and ECBA. These fractures seems to be extended down to 15-20 km depth, based on the the delay times (0.21-0.26 s). A rheological profile within the deepest area of the FD shows a good correlation between the transition zone from the brittle to ductile behaviour and the distribution in the depth of crustal foci, both for the compressional and extensional stresses. Finally a integrated interpretation of the above data is done.

T2-12

SEISMIC AND GRAVITY STUDIES OF TWO CONTRASTING GRANITES IN THE CZECH REPUBLIC

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The mechanism of granite emplacement remains one of the outstanding unanswered questions of geology, in spite of the fact that the generation and intrusion of igneous material is of primary importance in the formation and evolution of continental crust. Unfortunately, there are few detailed studies of the three dimensional geometry and boundary zones of igneous bodies. However, modern seismic techniques offer a possible solution to this dilemma. We are reprocessing and interpreting a recent seismic reflection line from the Bohemian Massif of the western Czech Republic. This line crosses both the sharply discordant, high-level Karlovy Vary pluton (KVP) and the less evolved, deep-level, semi-concordant Central Bohemian pluton (CBP). These two plutons have strongly contrasting geophysical signatures, with the KVP showing a strong negative (~60 mGal) gravity anomaly and the CBP showing no distinct gravity anomaly. These gravity signatures agree with seismic determinations of the pluton bases. We intend to produce depth and mass models for these two contrasting plutons using a combined seismic, gravity and structural study. These models will then be used to test prevailing theories of magma generation and emplacement.

T2-13

ELECTRICAL CONDUCTIVITY STRUCTURES OF THE SOUTHERN CANADIAN CORDILLERA AND ITS RELATIONSHIP WITH OTHER GEOPHYSICAL AND GEOLOGICAL DATA.

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The southern Canadian Cordillera of western Canada lies in a region of oceanic and island-arc lithosphere accreted to North America during subductions over the last 200 Ma. The crust is a complex of accreted terranes detached from their subducted lithosphere. The MT data has been split into four sets showing different regional electrical strikes. The models obtained are similar in most features, this indicates that although some data show 3D behaviour the responses can still be inverted in a 2D manner to obtain a broad regional pattern of the conductivity structure in the Canadian Cordillera. To first approximation the resistive upper crust of the Canadian Cordillera can be related to structural or seismic structures, however the more conductive lower crust must be related to metamorphic episodes occurred after the accretion of the terranes. The main topic of this paper is to present a regional electrical structure of the Canadian Cordillera to explain the main features of the MT data and its relationship with other geophysical and geological data.

T2-14

ON THE NACP CONDUCTIVITY ANOMALY GEOPHYSICAL SIGNATURE

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The Paleoproterozoic Trans-Hudson Orogen (THO) extends from southern South Dakota north through North Dakota and Saskatchewan, then swings eastwards through northern Manitoba into Hudson Bay. The first geophysical evidence for the extent of the orogen was the North American Central Plains (NACP) conductivity anomaly discovered by Camfield and Gough (1977) using a GDS array survey. In this paper, we present the results of the natural-source magnetotelluric (MT) studies along nine profiles from North Dakota to the exposed orogen in Saskatchewan. The NACP anomaly had been associated with metasedimentary sequences deposited between the advancing La Ronge arc and Rae-Hearne Archean hinterland. Analysis of hand sample rocks in the exposed orogen had shown that the only conductive rocks belong to a sedimentary unit that contains sulfides. The trace of the NACP anomaly is very uniform along all the profiles, except for profile N, where it reaches its maximum width.Valid geodynamic models of the orogen must explain both, the enhancement of the conductivity and the trace of the anomaly. In addition, a comparison between the MT and seismic profiles is shown where are spatially coincident.

T2-15

CRUSTAL STRUCTURE ACROSS THE CORDILLERAN OROGEN OF NORTHWEST BRITISH COLUMBIA FROM *LITHOPROBE* AND *ACCRETE* SEISMIC DATA

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The northwestern Cordillera of North America (British Columbia and SE Alaska) is comprised of a complex assemblage of terranes accreted to North America during two distinct periods. In the early Jurassic, the Intermontane superterrane (Stikinia, Cache Creek, Quesnellia, Slide Mountain and Cassiar terranes) was thrust eastward over North America. During the mid-Cretaceous, the exotic Insular superterrane (Alexander and Wrangellia terranes) collided with North America, further deforming the Intermontane terranes and producing the Coast orogen. The history and 3-D geometry of many of these terranes are poorly understood. The LITHOPROBE Slave-Northern Cordilleran Evolution (SNorCLE) and ACCRETE transects target this geotectonic environment to investigate the growth of continents by magmatic and terrane accretion. The SNorCLE Refraction Experiment (SNORE97) Line 22 extends south from the Tintina Fault, across the Intermontane terranes and into the Coast orogen suture zone. Nine explosive shots (1000 - 3000 kg) were detonated along the 500 km profile. Recording was accomplished using 450 seismographs positioned every 1 km with the one-component (PRS and SGR) and three-component (REFTEK) instruments interspersed. The ACCRETE seismic experiment utilized the coastal fjords to profile crustal structure from the Pacific Plate through the Coast orogen. A 132 l airgun array, shooting along a 200 km long fjord, provided the seismic source for 60 REFTEK seismographs, seventeen of which were deployed northeast from the head of the fjord, thereby directly linking ACCRETE with SNORE97 Line 22. The two resulting wide-angle datasets provide a densely sampled, 2-D profile. Data quality from both experiments are excellent; numerous reflected and refracted P- and S-phases are identifiable and are observed to large offsets. Data analyses of the SNORE97 dataset include initial 1-D velocity modeling using -P analysis and subsequent 2-D velocity modelling using traveltime inversion and ray amplitude forward modelling. Velocity structure and wide-angle reflection models will be presented. Analyses of the SNORE97 Line 22 data will be integrated with the ACCRETE P-velocity, S-velocity and Poisson's ratio models. Coincident near-vertical incidence reflection data were acquired beneath the ACCRETE profile and will be acquired beneath SNORE97 Line 22 in late 1998.

T2-16

COMPARATIVE ANALYSES OF REGIONAL GEOLOGICAL AND GEOPHYSICAL DATA SETS BY APPLICATION OF GEOGRAPHICAL INFORMATION SYSTEMS

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Analyses of regional geophysical (primarily gravity and magnetic) maps in western Canada using various filtering techniques provide opportunities to relate the anomaly patterns to surface geological data, as well as to seismic profiles. Maps of common geological features (e.g., faults, plutons, geotectonic belts) are individually overlain on different bandpass and directionally filtered versions of the gravity and aeromagnetic maps. Important features that are observed include: (1) northeast striking anomalies of the Canadian Shield that can be followed through the young Cordillera to nearly the Pacific coast, and (2) a north-striking anomaly associated with the Eocene Fraser River strike-slip faults that can be followed for more than 600 kilometers north of its known exposure. These patterns indicate that surface structures of the Cordillera have different orientations from deep structures, and are likely detached from them.

T2-17

WAVENUMBER FILTERED POTENTIAL FIELD ANOMALIES OF WESTERN CANADA

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Application of wavenumber filtering techniques to potential field data provides an opportunity to analyze anomaly map patterns in relation to their tectonic setting. Here, we compare lowpass, bandpass and directional highpass filtered versions of the isostatic gravity anomalies of western Canada to regional structures interpreted on crustal seismic profiles. Bandpass, lowpass and highpass filtering allows separation of anomalies according to wavelength, which can be related to the depth and size of source. Directional filtering allows separation of anomalies according to azimuth, which can be used to remove or enhance regional tectonic trends. Crustal seismic profile along the eastern margin of the Canadian Cordillera, from the U.S. border to the Beaufort sea, provide detailed subsurface crustal geometry over a distance of about 2000 km. Comparison to filtered potential field data by way of 2.5-D models allows the subsurface structures to more easily be linked to specific map anomalies. For example, the seismic profiles image a west-facing crustal scale ramp which produces a gravity anomaly that can be followed for over 1000 km. This feature probably represents buried western margin of the North American craton.

T2-18

A MULTIDISCIPLINARY VIEW OF LITHOSPHERE IN THE BETICS AREA (SOUTHERN SPAIN)

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Magnetotelluric soundings, earthquake tomography, seismic refraction profiles and the ESCI-Betics deep normal incidence seismic reflection data characterize the litHosphere beneath the Betics. The analysis of these three different datasets suggests that the Betics orogen consists of the juxtaposition of two crustal domains characterized by distinctive physical properties. According to this, the Iberian Crust features a relatively high seismic velocity, is seismically transparent in the seismic reflection images and is electrically resistive. The Alboran Domain crust is characterized by a low average velocity, displays high reflectivity in the seismic reflection images and is electrically conductive. The outcrops of the metamorphic complexes (Alpujárride and Nevado Filábride) show relatively high velocities coupled with low values for the Wadati slopes Vp/Vs of 1.67 revealing the existence of rocks rich in silica beneath the Alboran Domain crust. An interpreted detachment at 12 km depth imaged by the deep seismic reflection suggests that these rocks could be related to the Iberian Upper crust. At depth the tomographic images contrast with the normal incidence deep seismic reflection sections indicating a non- coincidence of the petrological and the seismic Moho beneath the Betics chain.

T2-19

CRUSTAL AND UPPER MANTLE VELOCITY STRUCTURE OF THE BETICS AND ALBORAN SEA REGION

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We have performed a 1-D and 3-D structural study of the Betics-Alboran Sea region using local earthquake P and S phase arrival times. The 1-D study constrains the depth of the Moho under the Betics region to lie somewhere between 28 km and 38 km depth. An average Vp velocity for the crust of 6.0 km/s and Vs velocity of 3.5 km/s is obtained giving an average Vp/Vs ratio of 1.71 for the Betics region. The 1-D study of the Alboran Sea constrains the Moho to lie somewhere between 20 km and 38 km depth. An average crustal velocity of Vp=6.4 km/s and Vs=3.5 km/s and hence a Vp/Vs ratio of approximately 1.84 is obtained for the Alboran Sea. We present a 3-D velocity model obtained for parts of the Betics-Alboran Sea region, constrained by standard error and resolution estimates.

T2-20

CRUSTAL REFLECTIVITY AT THE KTB SUPERDEEP HOLE: NEW INSIGHTS FROM WELL LOG DATA

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The most striking reflective features recognizable on reflection seismic profiles across the KTB superdeep hole have been explained by the presence of a main fault zone, the Franconian Lineament giving rise to the SE1 reflector and associated reflectivity. Cavings and borehole enlargements did negatively affect the acquisition and the quality of acoustic and density logs at depth and within the depth range of this geological feature. Careful reprocessing of acoustic logs, including recalculation of acoustic travel times, has allowed us to eliminate spurious readings and to obtain a more accurate acoustic velocity profile for the fault zone and for the underlying section. On the recalculated acoustic travel time profile this entire section can be characterized as a zone of relatively low velocity. Rocks of heterogeneous composition (metabasites, variegated sequences and paragneisses) were intersected within the depth range analyzed. The gneissic rocks around 8000 m display velocities lower than those of the gneissic rocks intersected in the first 1000 m section of the KTB hole. These results require now of further analysis of the existing geophysical and geological data to explain the decreased velocity beyond the fault zone at depth.

T2-21

EMISSION TOMOGRAPHY. STUDY OF STRUCTURE AND EMISSION ACTIVITY OF THE CRUST BENEATH VOLCANIC AREA IN NORTHERN KANTO, JAPAN.

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Coda of local earthquakes and seismic prehistory before P-waves of earthquakes was used to study structural and emission features of the crust beneath the volcanic front area in the central Japan. Method of Emission tomography was applied, which permits to locate sources of a weak seismic signal, estimate amplitude and spectrum of a seismic radiation. Analysis of coda permits to detect scattering regions, analysis of noise field permits to detect active volumes connected with active geodynamic processes, with a seismic emission effect being a kind of the trigger effect in the energy-saturated Earth. Locations of active and scattering volumes revealed from emission tomography study of coda and noise field are in a good agreement with each other and with spatial distribution of low-velocity and P-waves high-attenuation anomalies receive by Japanese seismologists. Detected anomalies relates to the real geophysical objects: tectonic faults, middle crust magma body, area of location of large earthquakes.

THEME 3: Imaging 2D and 3D heterogeneities and anisotropy

T3-01

WHAT ARE PN VELOCITIES TELLING US ?

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Observation of Pn phases in many refraction data sets generated by controlled explosive sources and in earthquake records is a wide-spread phenomenon. Pn velocities usually range between 7.8 and 8.2 km s-1, with 8.09 km s-1 taken as a global continental average. In the frame of classic ray theory these observations suggest a positive upper mantle velocity gradient for compressional waves. From a petrological point of view this positive gradient doesn't come as natural as the seismological interpretations. The upper mantle sub-Moho mineralogy is well known from many mantle samples provided by xenoliths and exposed lower crustal and mantle sections. Given a certain composition the in situ velocities are controlled by the competing effects of pressure and temperature increasing with depth. The velocity values at a reference pressure and temperature are modified with appropriate partial derivatives with respect to temperature and pressure. Normal geotherms as expected for the continental average, for equilibrated crust, and high heat flow areas always result in negative velocity gradients. Only in areas such as along Precambrian shield with a very low mantle heat flow and associated temperatures is a slightly positive gradient possible. Petrological evidence would thus predict that a Pn phase is rarely observed with the exception of cold platforms and shields. This antagonism was for some authors one argument to account for anisotropy increasing with depth. We show that the familiar view on Pn phases does not apply to media, that contain random velocity fluctuations superimposed on long-wavelength structures such as positive or negative velocity gradients. If short-wavelength random fluctuations of only 0.5-1% are added to the velocity values of a negative gradient a phase with an apparent velocity corresponding to the upper limit of the velocity step at Moho depth emerges.

T3-02

THE BASIN AND RANGE REVISITED

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We have developed a deterministic-stochastic model for the crust of the northwestern Basin and Range Province, western North America, based on the reprocessed and reinterpreted nearly coincident COCORP 40° N vibrator reflection profiles 1, 2, 3, and 7 and the East-West PASSCAL Basin and Range refraction profile. The wide-angle data provide the deterministic velocity field and stochastic properties of the Moho, whereas the reflection data provide the stochastic components of the velocity field within the crust. With the exception of the near surface and complexity at the Moho, the wide-angle data provide a relatively simple deterministic velocity field. Where vibrator reflection data and densely sampled dynamite data are both available they are in agreement in estimates of stochastic parameters throughout the crust. Across the more extensive vibrator profiles the Basin and Range middle and lower crust have scale parameters in the range 200-800 m, corresponding to visual scales of 450-1800 m. The scale parameters are banded vertically and laterally, with less than half of the crystalline crust having scale parameters greater than 400 m. Scale parameter is not simply correlated to reflection amplitude, and, as long as signal penetration is adequate, the scale parameters are related to the sized of reflecting objects in the crust. We interpret the lateral scale parameters as being the size of mafic intrusives in the lower and middle crust. The amplitude with offset response of the wide-angle reflection PmP can be matched by introducing a stochastic variation in depth to Moho comparable in amplitude and lateral scale to the basement topography.

T3-03

ANALYSIS OF UNUSUALLY HIGH-QUALITY SHEAR-WAVE WIDE-ANGLE RECORDS FROM *ACCRETE* EXPERIMENT, SE ALASKA

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Wide-angle records obtained during the '94 ACCRETE transect across the Coast Mountains, SE Alaska, are characterized by unusually abundant and high-quality S-wave recordings. Direct S waves are observed continuously up to 110 - 150 km offsets; P/S (S/P) Moho converted phases and SmS reflections can be traced to nearly zero offset. A bright SmS reflection is probably observed beneath the Coast Mountains Batholith (CMB). High-amplitude S waves generated by the airguns are associated with the effect of the sediment cover of the bottom of the Portland Canal fjord. The S-wave travel times are analyzed using a combination of travel-time tomography with 2-D forward travel-time modeling accounting for P/S conversions and corrected for the crooked-line geometry of the profile. Preliminary results of S-wave pre-stack migration corroborate this model and demonstrate variations in the Moho S-wave reflectivity under the CMB. Variations of S-wave crustal velocity structure, the character of reflectivity, and Moho topography correlate with the boundaries of imaged tectonic structures. By cross-correlating different components of the records and by using instantaneous polarization attributes, we observe S-wave splitting in the direct arrivals and in the reflections from the Moho resulting in constraints on crustal anisotropy.

T3-04

RESOLUTION PROPERTIES OF A *BABEL* SECTION (LINES 1, 6, 7) AND 3-D RECONSTRUCTION FROM EXPANDED WIDE-ANGLE DATA

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The 3-D velocity structure of the Bothnian Bay crust was obtained on the basis of refracted and reflected P-waves data for BABEL lines 1, 6, 7. New data from the stations BS3 and BS4 were also used for lines 6&7. The parameters of the initial model were obtained by methods of mathematical modeling. It was shown, that the best resolution is achieved with block size 50x50 km2 up to the depth of 60 km. This investigation confirms the position of Moho depression.

T3-05

ESTIMATING THE RESOLUTION OF VELOCITY FROM 3D SEISMIC REFRACTION DATA

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A method for estimating the lateral resolution of velocity from 3D seismic refraction traveltimes is presented. Synthetic data calculated from checkerboard models are inverted using a tomographic approach incorporating smoothness constraints. Two applications are presented: (1) the real data from the 1993 Faeroe Basin experiment with ~50,000 picks, and (2) the ideal data set from the same experiment corresponding to 100% data recovery, or ~150,000 picks. A series of checkerboard models consisting of alternating 5% anomalies superimposed on the preferred final model of the basin were tested, each with a different cell size, registration and/or orientation. The local semblance between the known and recovered checkerboard patterns is measured at each node of the model. A semblance threshold of 0.7 is used to determine the smallest well-resolved cell size at each node and thereby provide a spatially-dependent lateral resolution estimate. The results illustrate the pitfalls of using ray coverage as an indicator of resolution, and demonstrate the potential resolution of currently feasible 3D experiments. The results for the ideal data show that 3D refraction experiments can provide a lateral resolution of roughly half the shot (receiver) spacing to about the same depth, and no worse than the shot (receiver) spacing throughout the sampled volume for typical land (marine) data.

T3-06

SUBCRUSTAL SEISMIC ANISOTROPY BENEATH THE IBERIAN PENINSULA: A REVIEW

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The Iberian Peninsula and its well differenciated tectonic domains provide a suitable framework to try to discern the presence and origin of subcrustal anisotropy. During the last decade, a number of groups, using different data sets, have investigated this topic. In this communication we report the main results available up to now. By analysing the azimuthal variations of the P-wave velocities from the ILIHA deep seismic sounding profiles, a fast velocity direction (FVD) oriented roughly N10°E has been inferred beneath the Ossa-Morena zone (SW Iberia). This anisotropy was restricted to some well defined depth levels between 60 and 90 km. Splitting observations on teleseismic shear waves recorded by a portable network installed in the same area, suggested a NE-SW to E-W FVD. Using SKS data from the permanent station in Toledo (central Iberia), different authors inferred in the late 80's a FVD oriented close to N90°E. The NARS-ILIHA teleseismic experiment, a network of 14 broad-band stations deployed over Iberia for about one year, provided a significant increase in the number and spread of anisotropy observations. The stations located in Central and East Iberia show a FVD oriented roughly E-W and a significantly different NE-SW FVD is observed in the Ossa-Morena zone, confirming previous results. The FVD inferred from the stations located in the Internal Betics, oriented N15-35E, is clearly different from the N80E one observed in the limit of the External Betics. A FVD beneath the central Pyrenees oriented N100°E has been reported using data from a temporary network deployed around the ECORS profile. The eastern and western Pyrennes have also been investigated along two profiles crossing the chain, providing similar results. At a larger spatial scale, the investigation of the surface waves recorded by the ILIHA-NARS network, has shown that anisotropy should be present beneath depths of 100 km. The regional variations in the anisotropic parameters documented in Iberia imply that differenciated origins of the anisotropy related to particular lithospheric geodynamics have to be considered.

T3-07

THE EFFECTS OF VELOCITY ANISOTROPY ON SEISMIC REFRACTION DATA AND ITS ANALYSIS: AN EXAMPLE FROM SOUTH ISLAND, NEW ZEALAND

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Velocity measurements made in the laboratory on rocks collected from the chlorite, biotite and garnet schist zones of the Southern Alps orogen, South Island, New Zealand show significant (17%) anisotropy. In 1996, a crustal-scale seismic refraction/reflection experiment was conducted across this highly anisotropic region. We show that the anisotropy measured in the laboratory can be seen in the seismic refraction data by looking at a dataset collected offshore South Island, New Zealand with a geometry designed to sample directions parallel and perpendicular to the schist foliation onshore. When creating velocity models by forward modeling or inverting travel-time arrivals from seismic-refraction data, we usually assume a heterogeneous, but isotropic earth. In regions where the earth is not isotropic at the scale it is being sampled, the assumption of isotropy can lead to significant errors in the velocities determined for the crust. We demonstrate why it is important to include anisotropy when modeling data from such locations using finite-difference full-wavefield modeling. We then discuss the implications for South Island, New Zealand, where the problem may be compounded by extreme orientations of these highly anisotropic rocks at the Indo-Pacific plate boundary, e.g. schistosity aligned with directions between 0 and 90° from horizontal.

THEME 4: Intracontinental collisions

T4-01

INDEPTH III: PRELIMINARY RESULTS FROM 1998 SEISMIC REFLECTION SURVEY ACROSS THE BANGGONG-NUJIANG SUTURE, CENTRAL TIBET.

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INDEPTH (INternational DEep Profiling of Tibet and the Himalayas) phases I and II acquired transects across the High Himalaya and the Yarlung-Zangbo suture, and through the Yangbajain rift, at around 90°E (Nelson et al., Science, 274, 1684, 1996). In Phase III (summer 1998) Sino-US-German teams will carry out new controlled-source and earthquake recording, magneto-telluric imaging and geologic mapping, principally along a 400-km-long NNW-SSE corridor from Longwei Co (Lake) across the Jurassic Banggong-Nujiang suture (separates the Qiangthang Block from the Lhasa Block to the south) to the west side of Nam Co. This transect is planned to cross the northward limit of subduction of India beneath Asia (the "mantle suture"), believed to lie beneath the Tertiary Lumpola Basin. Seismic goals of INDEPTH III include recording a northward continuation of the profiles produced in INDEPTH phases I and II, observation of PmP and Pn to construct velocity models of the crust, and recording deep-crustal reflections. We anticipate imaging the Lumpola Basin and underlying crust, including changes (if any) in the reflectivity fabric across the Banggong-Nujiang Suture. In addition we will search for seismic bright spots (and coincident conductivity anomalies), such as found during INDEPTH II, that may indicate the presence of mid-crustal partial melt or water. During the controlled-source part of INDEPTH III c. 60 broadband three-component sensors will be deployed with c. 8 km spacing along the 400 km profile, with an additional 8 sensors placed off-line. Four large (1-2 tonnes), and three sets of 40 smaller (50 kg), dynamite shots will be recorded with this stationary array as well as with a local array (a 2 km, 60-channel Geometrics spread and 10 short-period seismometers with 1 km spacing) deployed at the three locations of the 40 smaller shots. We will present preliminary results from this active-source work. Following the controlled-source experiment, broadband instruments will be reconfigured for passive earthquake recording and left in place until August 1999.

T4-02

DEEP SEISMIC PROFILING AND TECTONIC EVOLUTION OF SULU UHPM TERRANE, EAST-CENTRAL CHINA

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The Dabie-Sulu High-pressure metamorphic (UHPM) belt is one of the best sites worldwide to study the intra-continental collision-subduction behaviors and the formation-exhumation dynamics. In order to select optimal site for continental scientific drilling in the UHPM belt, seismic surveys have been carried out in Sulu areas since 1996. The Sulu UHPM terrane is located in the far east part of the Central Orogenic Belt of China, between the Sino-Korean craton to the north and theYangtze craton to the south. Deep seismic reflection and MT lines of about 190 km across the Sulu UHPM terrane have been completed, producing high-quality records and rich geological information about crustal structures. The results include (a) The Sulu UHPM and HPM terrane is a wedge-like rock-massif with high velocity and resistivity, dipping northwest and undergone heavy deformation, implying its subduction and then exhumation during Triassic Period; (b) the Yangtze craton, showing as a bent plate with normal velocity and relatively low resistivity, was subducting northward beneath the Sulu UHPM terrane, containing a lot of wedge reflectors related to the collision between the Sulu and theYangtze; (c) both the old Moho of the Indosinian subducting of theYangtze crust and the new Moho formed after Indosinian Movement have strong and clear reflectors, indicating strong magmatic activities and interaction between the crust and the mantle during Mesozoic Period when which contributed to the formation the new Moho; (d) seismic profiles show clear trails of mantle upwelling and rifting probably occurred at146 Ma, which might also contributed to the exhumation of the UHPM rocks; and (e) a group of thrusts exists in the upper crust under south Sulu, they might indicate progressive exhumation of the UHPM rocks and encourage the scientific drilling in the South Sulu area whose aims include revealing the exhumation dynamics of the UHPM massif.

T4-03

CRUSTAL-SCALE STRUCTURAL GEOMETRIES OF THE CHICXULUB IMPACT FROM BIRPS SEISMIC REFLECTION PROFILES

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The deep seismic reflection profiles and long-offset receiver records acquired during a BIRPS survey off the north coast of Yucatan in September-October 1996 have clarified the geometries of several major features of the Chicxulub impact structure. The most prominent reflectors observed on each of the four 150-200 km long radial profiles are related to a Jurassic-Cretaceous stratum at 2-3 km depths and to the Moho at 30-35 km depths. The Mesozoic reflector is relatively undisturbed throughout most of the Yucatan continental shelf, but becomes gently domed at about 120-130 km radial distance from the hypothesized 'ground zero' of the Chicxulub impact. A layer with more chaotic reflectivity, interpreted as impact breccia that includes significant amounts of melt throughout, separates the Cretaceous and Tertiary sedimentary sequences out to radial distances of 100-125 km. The lower crust is reflective throughout the survey area at depths greater than 20 km. The base of prominent reflectivity occurs at 30 km except beneath the impact structure where it deepens to 32-35 km levels. Three sets of dipping reflectors occur beneath the interior of the impact structure and these project up from about 25 km depth toward three varied deformation zones within the Mesozoic strata. These dipping reflectors within crystalline basement probably represent shear zones with their reflectivity possibly enhanced by mafic intrusions. If these shears were active during the impact or during the collapse phase, these intrusions could be related to melts generated deep in the crust by the impact.

T4-04

PROTEROZOIC AND CENOZOIC SUBDUCTION COMPLEXES: A COMPARISON OF GEOMETRIC FEATURES

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The discovery of mantle reflections along the LITHOPROBE SNORCLE transect in northwestern Canada that are interpreted as a relict subduction zone provides an opportunity to analyze geometric features of the data by comparing them to those of a modern convergent margin, the Cascadia subduction zone beneath and offshore Vancouver Island. Some features that are geometrically similar are: a subducting slab, an accretionary wedge, continentward steepening thrust surfaces within the accretionary wedge, a forearc basin, a possible fossil trench, and material attached to the bottom of the overriding plate by underplating. This approach provides a basis for interpreting the deep reflection profile where it is difficult to trace individual features to outcrop, as well as for determining the nature of ancient (ca. 1.9 Ga) tectonic processes in relation to processes observed today.

T4-05

THE KAPUSKASING STRUCTURAL ZONE: A PROTEROZOIC MOUNTAIN-BUILDING EVENT ELUCIDATED BY MULTIDISCIPLINARY

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The Kapuskasing Structural Zone (KSZ) is an enigmatic 400 km long, northeast-southwest trending, band of high metamorphic grade rocks in the western part of the Archean Superior Province of North America. Since 1984, Project LITHOPROBE has sponsored many different kinds of investigation of it. Although the interpretation of any one line of evidence often can be highly debateable, a coherent picture emerges from the sum. In summary, the KSZ is, as earlier postulated, a Proterozoic fault zone on which the main movement probably occuring around 1900 Ma (certainly between 2300 and 1800 Ma). However, the structure is not a simple compressional thrust verging from the northwest. Rather, it is a dextral transpressive zone involving about 5 degrees of clockwise rotation of the northwestern side with respect to the southeast, exhibiting not more than 50 km of transcurrent and 0-30 km compressive displacement. The large (as much as 25 km) relative uplift of some crustal blocks is related to ductile behaviour of the lowermost crust during the tectonic event that allowed the uppercrustal lid to be "popped" in some places. Deformation propagated progressively from NE towards the SW, and ceased before breaking through to the proto-Lake Superior basin. Erosion of uplifted parts of the crust on the same time scale as the propagation of the deformation was an important factor in the gedynamic process. The poster shows how the many lines of evidence interact to support this conclusion.

T4-06

MULTIPLE EPISODES OF CRUSTAL DEFORMATION IN A BROAD ZONE SPANNING THE BOUNDARY BETWEEN THE SHIELD AND YOUNGER TERRANES IN SE AUSTRALIA

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The Tasman Line is the boundary between the Proterozoic shield in central and western Australia and the younger Phanerozoic Belts in the east. SE of the Broken Hill Block, it has been interpreted as a transform margin during the break up of Rodinia, and is defined by NE-SW trending gravity and magnetic anomalies and a topographic feature defining the course of the Darling River. None of these is coincident. A seismic reflection and refraction transect revealed that the Broken Hill Block in the NW of the transect comprises several blocks separated by a 25-30 km wide deformation zone, in which SE dipping, apparently planar shear zones penetrate to middle to lower crustal levels. The shear zones are believed to be Proterozoic in age but topography across them implies recent movements. Predominantly SE dipping shear zones are also intepreted SE of the deformation zone. Some link into sub-horizontal detachment surfaces at 10-20 km depth, but others farther to the SE truncate against strong, NW dipping reflections in the middle to lower crust beneath the Phanerozoic terranes. They define a triangular shaped region in the crust at least 80 km wide which underpins the boundary between the shield and younger terranes. The upper crust in this region is largely unreflective, and is thickened in places, presumably by thrusting. The age of the presumed thrusting is indicated by deformation in sediment cover to be post Middle Devonian. The shear zones within the crust, including those which penetrate the whole crust and those clearly limited to the upper crust, form conjugate sets. The boundary between the shield and the younger terranes is therefore not a "line" but rather a broad deformation zone in which old structures in the NW continued to be active as younger deformation occurred to the SE.

T4-07

THE *MONA LISA* PROJECT - DEEP CRUSTAL SEISMIC MODELLING AND TECTONIC IMPLICATIONS

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In 1993 and 1995, three deep seismic profiles of a total length of 750 km were shot with an airgun array with a total volume of 127 l. Near-vertical incidence reflection data (CMP data) were recorded with a long record length, wide angle reflection/refraction data was recorded by Ocean Bottom Hydrophones (OBHs) and by land stations. The main targets of the project were the signature of the Caledonian Deformation Front (CDF) and the deeper crustal and upper mantle structure of the extensional features, mainly the Central Graben (CG) and the Horn Graben. The CMP data give good images of the sedimentary cover. The crystalline crust is generally low-reflective. In the upper mantle, several strong and coherent dipping reflections could be identified. The wide angle data were used for 2-D P-wave velocity modelling. Good control on the structure of the sedimentary was essential for interpretation of deeper structures. Velocity differences in the upper crust coincide with the proposed position of the CDF. Crustal thinning is seen underneath the CG. The wide angle velocity models were used for a depth migration of the CMP data, which gave very good images down to c. 70 km depth. 2 ½-D Gravity modelling is used to constrain the discussed structures. The results are discussed in a collision tectonic context.

T4-08

THE CONTINUATION OF TRANSFORM AND STRIKE-SLIP FAULTS INTO DEPTH: AN EXAMPLE FROM IBERIAN VARISCIDES

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Transform faults and strike-slip intraplate shear zones and faults must curve respectively toward the base of the lithosphere and décollement intraplate levels. The sense of curvature is towards the most rapid moving plate relative to astenosphere and crustal block, relative to deeper levels. As an example we can cite the Tomar-Badajoz-Cordoba shear zone in the Iberian Variscides, where a mid-crustal décollement connects two en echelon stepping left lateral transpressive flower structures. Seismic profiling will allow to establish the thin - or thick skinned character of Ossa-Morena Zone in the Iberian Terrane.

T4-09

GEOPHYSICAL INVESTIGATION OF THE JOINT BETWEEN PALEOZOIC DONBASS STRUCTURES AND KARPINSKY MOUNTAIN RIDGE

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During th 90's geophysical enterprises of Russia and geological service of the region obtained new data on the lithology and morphostructural characteristics of the Paleozoic sedimentary cover to the west of the open Donbass, within the PreCaucasus and Karpinsky mountain ridge. The information obtained leads to the conclusion that the size of the folding gerxinsky deformations in the region is considerably overestimated, while treating the terrigenous deposits as a domineering carbonate layers, together with traditional aleurolites and argilites. When carrying out seismic survey, oriented on investigating mesocainozoic sediments, the investigators increasingly discover extensive sub-horizontal or gently sloping reflections of Paleozoic horizons, thus testifying to considerable displacement of the rocks. Spetzgeophysika has been conducting geophysical survey in the region for 40 years and combined the data obtained with those of the other companies in order to develop new approaches to their interpretation. We took into consideration the seismic survey (DSZ, CRWM, MRW), carried out on Donbass and Cross-Donbass profiles. Re-interpretation of the data obtained on the DSZ-profile /XII/ oriented along the Donbass discovered the uplifting area on the refracting horizon at V=6.3 km to -5.0~-5.2 km. CRWM-profile (X) of 1964 across Donbass upon re-interpretation revealed the presence of high velocity, presumably carbonate rocks up to 3km layer. East Donbass body, presumably of Early Devonian-Bashkir carbonate (?) period, upon obtaining additional geological geophysical data confirming the interpretation, will be of prime importance for understanding the structure of the joint between Donbass and Karpinsky mountain ridge, and in the distribution of Paleozoic sedimentary cover in the Southern area of the East European platform. In accordance with the suggested program multi-method geophysical profiles of 550-600 km will be shot in order to prove the hypothesis and define the site of the body. Realization of the program began in 1997.

THEME 5: Transects and syntheses

T5-01

HOW THICK IS THE EARTH'S CRUST?

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We present a new contour map of the thickness of the Earth's crust. We use a 10 km contour interval plus the 45 km contour. This contour map was created directly from the 5 deg. by 5 deg. gridded crustal model CRUST5.1 (Mooney et al., 1998) plus complimentary information. An initial contour map was created using the command "grdcontour" in GMT, and the resultant map was adjusted in Adobe Illustrator to honor individual point measurements and newly available information from Russia. The final contour map honors all available seismic refraction measurements for features with a dimension greater than 2 degrees. To a first approximation, the continents and their margins are outlined by the 30 km contour. That portion of the continental interior enclosed by the 40 km contour, and regions with crustal thickness of 45 to 50 km are found on all well surveyed continents (i.e., N. and S. Am., Australia, and Eurasia). Continental crust with a thickness in excess of 50 km is exceedingly rare and accounts for less than 10 % of the continental crust. These observations, now available on a global basis, provide important constraints on the evolution of the crust and sub-crustal lithosphere.

T5-02

THE STATUS OF CONTROLLED SOURCE DEEP SEISMIC RESEARCH IN AUSTRALIA

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Australia has a long history of deep seismic research. Most research has been conducted by the Australian Geological Survey Organisation (AGSO), formerly the Bureau of Mineral Resources, although several short deep seismic reflection and a number of long range refraction experiments have been undertaken by university groups. AGSO now has over 7,500 km of profiling to Moho depths and beyond onshore, and over 73,000 km offshore. The research was designed to support a number of national initiatives, including defining Australia's offshore territorial boundaries under the United Nations Convention on the Law of the Sea, providing basic data for improved petroleum prospectivity analysis (offshore and onshore), providing the third, depth dimension for regional geological mapping, and to support studies into the geodynamic factors influencing the development of mineral deposits. The profiles offshore encompass the full gamut of passive margin styles, and volcanic and non-volcanic plateaux. The profiles onshore cross the boundaries major continental blocks, a number of sedimentary basins and several major mineral belts. AGSO, with the Australian National University, recently established a major national research facility to further this research. AGSO is actively involved in international collaboration in its research using its data base of seismic data, and welcomes inquiries from bona fide researchers interested in further cooperation.

T5-03

THE AUSTRALIAN NATIONAL SEISMIC IMAGING RESOURCE (*ANSIR*): AN INITIATIVE TO FOSTER RESEARCH AND EDUCATION IN SEISMIC IMAGING IN AUSTRALIA

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The Australian Geological Survey Organisation (AGSO) and the Australian National University (ANU) have established a Major National Research Facility (MNRF) in seismic imaging of the Earth. The facility is called the Australian National Seismic Imaging Resource (ANSIR). The Australia government provided A$5 million to support the construction and purchase of a suite of seismic recording equipment and vibratory energy sources for ANSIR. In supporting the establishment of MNRFs, the government has recognised that major scientific and technological advances are increasingly dependent on researchers having access to very expensive equipment and facilities beyond the resources of most institutions to finance. Lack of access to equipment has been a long recognised impediment to geophysics researchers and education in Australia. The recording equipment includes a seismic reflection recording systems, and both short period and broad band portable seismographs. The aim is to develop a facility that can support projects which image structures from continental to detailed in scale. Researchers have to find their project operating costs from traditional research funding agencies. Australian researchers are encouraged to use the facility to build collaborative links internationally. ANSIR should be fully operational in 1999.

T5-04

BALANCED SEISMIC VELOCITY DISTRIBUTION IN THE PRECAMBRIAN CRUST OF THE BALTIC SHIELD AND AUSTRALIA AND ITS PETROLOGICAL IMPLICATIONS

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Commonly, anomalously high velocity rocks in the Precambrian regions are underlain by anomalously low velocity rocks, and vice-versa, so that a balancing of high and low velocities ("seismic isostasy") can be seen along any vertical profile through the crust. In the Baltic Shield, velocity variations in the upper crust are compensated above the lower crust. Significant lateral variations in P-wave velocity at a mid-crustal level (20-35 km depth) underneath the Proterozoic Mount Isa Inlier (Australia) are also compensated within the crust well above the Moho. A similar conclusion can be derived from the analysis of average velocity-depth functions from other Australian Precambrian terranes. These results are consistent with the data collected by different seismic methods, including vertical seismic profiling in the Kola Superdeep Bore Hole (KSDBH) in the northern Russia. Direct pressure estimates from the KSDBH density measurements confirm that regions with high velocity and density in the upper crust may be isostatically compensated by the low velocity and density regions well above the Moho, but the possibility of global translation of "seismic isostasy" into conventional isostasy is a subject for further studies. Under certain PT-conditions seismic models with balanced velocity distribution translate into petrological models, whereby the averaged SiO2 content in the upper 35 to 45 km of the Precambrian crust studied is very similar despite significant differences in composition occuring throughout the crust. Therefore the Precambrian crust, particularly in the top part, has remarkably similar overall composition, and the apparent differences in seismic models can mostly be explained by different thermal regimes affecting equilibrium mineralogies at depth.

T5-05

THE OPHTHALMIAN OROGENY, SYLVANIA DOME: RESOLUTION OF THE DEFORMATION EVENTS IN THE THIRD DIMENSION USING DEEP SEISMIC TECHNIQUES

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The Archaean Sylvania Dome is a granite-greenstone terrane overlain by the late Archaean to early Proterozoic mafic and felsic volcanics, intrusives and sediments of the Hamersley Basin. The Hamersley Basin includes voluminous economically significant iron formations. Part of a major deep seismic survey, recently conducted within the region, focused on imaging structures within the Sylvania Dome to develop a better understanding of the relationships between and interaction of each of the deformation events documented within the Sylvania Dome and overlying Hamersley Basin. Three distinct orogenic episodes have been documented. The first episode is Archaean , with three deformation events recognised. The second episode is an early Proterozoic event (~2200 Ma, Ophthalmian Orogeny) that was responsible for a series of major shear zones within the Sylvania Dome that cut across the earlier D2 and D3 structures and for the major folding within the overlying sequences. It occurred as a result of block movements in the granite-greenstone basement. The third episode is the Capricorn Orogeny (~1800 Ma) and resulted in uplift in the overlying sequences. The deep seismic results clearly image a series of south dipping planar shear zones which penetrate to lower crustal levels. These shear zones correlate with mapped Ophthalmian Orogeny shears zones. This paper will demonstrate the use of deep seismic to determine the relationship between the Archaean deformation events and the more recent Ophthalmian shear zones, as well as the nature of the deeper crustal architecture.

T5-06

THE CRUSTAL STRUCTURE IN NORTHWEST CHINA

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We present a new crustal cross-section across northwest China based on a seismic refraction profile and geological mapping. The 1100 km-long seismic refraction profile, located on the northwesternmost part of the Geoscience Transect from Taiwan to Altai, crosses the southern margin of the Altai block, the Junggar Accretional Belt, the Tianshan Accretional Belt and the Tarim Platform. P- and S-wave seismic data acquired along this profile were used to model both the crustal velocity structure and Poisson's ratio in a section through the crust and upper mantle. The largest difference in crustal thickness is located at the northern end of the profile, where over a distance of <400 km, it varies from 54 km thick under the Altai block to 46 km thick under the Junggar Basin. On the southern side of the basin, the crustal thickness increases to about 49 km, and it remains this thickness over the rest of the southern portion of the profile, with only slight variation. Higher velocity crust with Poisson's ratio of σ=0.25-0.28 (Vp/Vs=1.73-1.81), observed below the Junggar Accretional Belt, may imply either a mafic crystalline Precambrian basement or imbricated Paleozoic accretionary belt, whereas the lower Poisson's ratios σ=0.25-0.26 (Vp/Vs=1.73-1.76), modeled through the crust in the Tianshan province, may imply a more granitic composition. The upper and middle crust of the Tarim Platform has a Poisson's ratio of around 0.25 (Vp/Vs=1.73), with lower average P-wave velocities than the Tianshan accretional belt (6.0-6.3 km/s and 6.1-6.5 km/s, respectively), suggesting highly fractured units in the Tarim Platform. A mid-crustal low-velocity layer (Vp=5.9 km/s, σ=0.25) straddles the Tianshan-Tarim boundary and is underlain by a lower crust, suggesting that Kushui Fault probably indicates the boundary between Tianshan fold belt and Tarim platform. Observed Pn velocities seem to vary with tectonic province as we observed Pn velocities of 7.7-7.8 km/s between Bogdashan and Tianshan and 7.9-8.0 km/s below the Altai fold belt and Tarim Platform.

T5-07

THE SYNTHETIC RESEARCH OF SEISMIC SOUNDING DATA OF LINGBI-FENGXIAN IN THE EAST OF CHINA

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LingBi-Fengxian geoscience transection (HQ-13 line) 500 kilometers in length in the east of China is a synthetic regional geology and geophysics section which traverses the south-east edge of north china plate, TanLu fracture, Haijiao massif and Yangtzi plate from Lingbi of Anhui province in the west to Fengxian of ShangHai in the east including 430 kilometers' vertical reflection seismic data, 70 kilometers' wide-angle seismic sounding data and other geophysics data. It can be used to investigate the structure of crust, all kinds of geological phenomena and laws of evolution in the scale of this section. In order to raise the efficiency of data and precision of explanation, we combine dive CT techniques with time field to draw 2-D velocity structure picture and explain vertical reflection data that traverses TanLu fracture again to study the delicate structure of TanLu fracture. Furthermore, we gain the consistent cognition through contrasting vertical reflection seismic data with wide-angle seismic sounding data. (1) The section was divided into upper part, middle part and lower part and at two sides of TanLu fracture the characteristics are different and the thickness of upper crust is 10-12 kilometers or so. It is a synthetic reflection of graben basin that surface structure changed a great deal in transverse. The thickness of middle crust is almost 10 kilometers. The velocity increase with positive gradient in the west of TanLu fracture but in east of TanLu fracture middle crust which bottom interface is 22 kilometers or so in depth is characterized by unequal low velocity massif that changed a great deal in transverse. (2) According to velocity structure isogram picture and appearance of mass structure seven fractures consisting of two crossing Moho fractures, one two term composite fracture, two Y-fractures and two internal crust fractures were identified. Specially, the dip of all fractures is easy to be acquired from the velocity structure picture. (3) Through the explanation we can draw a conclude that Moho is one transitional belt which changed a great deal in transverse and has certain thickness and the maximum thickness is 6 kilometers in the profile. (4) TanLu two fracture were regard as a composite fracture, which was composed of vertical strike-slip fracture and nappe fracture that corresponds to the bottom interface of low velocity massif.

T5-08

GEOTRANSECTS ACROSS THE ARCHAEAN-PROTEROZOIC TERRAIN OF THE INDIAN SHIELD

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The main objective of a geotransect is to produce interpretative cross-sections extending at least up to the base of the earth's crust, using the velocity and reflectivity structure along with other geophysical and geological parameters. With this aim two geotransects in Archaean-Proterozoic terrain of western and central India have been compiled. In the eastern Indian geotransect across the Delhi-Aravalli Fold Belts the lithological, reflection seismic, gravity/magnetic and magnetotelluric data have been synthesized along a 400 km long and 100 km wide corridor where intense and repeated tectonic deformation has been reported. Significant results indicate thick-skinned tectonics, a deep thrust boundary and intrusion of high density mantle material. The crust-mantle boundary is generally at depths between 38 and 42 km but reaches 45-50 km depth in some sections of the Archaean. Similar studies in a 450 km long corridor in central India show a lower crustal intrusive body at very shallow depths, presence of a suture zone - with tectonically imbricated crust on both sides - and crust-mantle boundary at 40 to 44 km. A synthesis of the two transects and their relevance to evolution of the northern peninsular shield are discussed.

T5-09

CONSTRAINTS ON UPPER MANTLE P-WAVE ATTENUATION FROM THE NUCLEAR EXPLOSIONS OF THE RUSSIAN DEEP SEISMIC SOUNDING PROFILE "*QUARTZ*"

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The ultra-long Deep Seismic Sounding (DSS) profile "Quartz" crosses 6 major geologic provinces in Eurasia and is sourced by 3 nuclear (PNE) and 48 chemical explosions. Based on the crustal and mantle velocity structure obtained in our previous travel-time and amplitude analysis, we derive a 2-D image of the upper mantle attenuation down to about 500 km depth. Two independent constraints are employed in our attenuation measurements: 1) estimates based on the inversion of the first arrival spectra using a modified common spectrum technique followed by least-squares inversion for Q and iterative ray tracing, and 2) spectral analysis of the long-range Pn phase, indicating a sharp attenuation increase at about 150 km depth. The resulting 2-D attenuation structure corroborates an earlier model for the Northern Eurasia and provides significantly more detail demonstrating seismic heterogeneity of the upper mantle. The resulting upper mantle attenuation structure is characterized by Q values ranging between 800 and 2000, with higher attenuation within the asthenospheric LVZ and also within a relatively thin LVZ imaged within the base of the lithosphere. Down to the depths of 150 - 190, and probably, 400 km, the attenuation increases horizontally in SE direction, away from the Baltic Shield suggesting extensive involvement of the upper mantle in tectonic processes.

T5-10

UPPER MANTLE INVOLVEMENT IN REGIONAL TECTONICS FROM A COMBINED INTERPRETATION OF THE PNE PROFILE "*QUARTZ*", RUSSIAN EURASIA

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The ultra-long profile "Quartz" is a part of the unique Russian Deep Seismic Sounding (DSS) data set that provides an unusual opportunity for studying of the upper mantle using controlled-source seismic methods. Our interpretation is based on the detailed crustal and upper mantle velocity structure derived from refracted and reflected seismic phases from all 48 chemical explosion and 3 PNEs of the profile. The lithosphere decreases in thickness from about 200 - 220 km under the East European platform to 100 - 120 km under the Altay-Sayan Mountains, with the corresponding increase of the P-wave attenuation from $Q \approx 2000$ to $Q \approx 800$. Our velocity/attenuation model suggests 3 regional, nearly continous seismic lithospheric boundaries imaged between 65 - 80, 120 - 140, and near 200 km depth. High velocity (8.4 km/s) uppermost mantle is found under the Mezenskaya depression and under the east flank of the Urals. A prominent low-velocity, high-attenuation layer within the base of the lithosphere, thickening under the West Siberian Basin, may probably be associated with the presence of partially molten and wet peridotite at this depth, or, alternatively, it may be related to the failed West Siberian rifting during the Triassic. The observed regional variations of the velocity and attenuation extend near the 410-km discontinuity, suggesting strong involvement of the upper mantle in tectonic processes. Also, the PNE data suggest a possible SE dip of the 410-km discontinuity and an about 15-20 km thick impedance gradient across it.

T5-11

THE SOUTHERN URALS TRANSECT - *URSEIS '95* - PRESERVATION AND ORIGIN OF PALEOZOIC COLLISIONAL FABRICS

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The crustal scale seismic image of the Southern Uralide orogen from the vibroseis and explosive-source CMP-reflection profiling of the URSEIS '95 experiment shows a preserved doubly vergent belt with a significant crustal root, as the result of two major partly superimposed collisional events: (1) the development of a Devonian W-facing accretionary complex and (2) a Permo-Triassic collision with the eastward accretion of the Transuralian terranes. While the E-vergent accretionary prism involves the entire crust with the Moho as the basal detachment, the thick-skinned W-vergent structures only include the upper part of the crust, suggesting different rheologies of the plate fragments and collisional processes. Restricted thermal influence across the entire Urals emphasizes that the compositional features of the involved crustal units take the main role: mafic to intermediate rocks dominate in the accreted Siberian island arc and oceanic collage, while the former passive margin of the East European craton is probably controlled by a quartz-feldspar rheology. Correlation with tectonics show the present day bivergent reflectivity as the sum of several orogenic imprints, keeping the memory of highest strain rather than resulting from a progressive and continous collisional process. The orogenic root as defined by wide-angle data is also fairly imaged by the explosive-source reflection data. Gravity and petrophysical modelling suggest that the crustal root is composed of mafic eclogitic rocks with properties close to upper mantle which inhibit prominent Moho reflectivity as in the fore- and hinterland. In contrast to other Paleozoic mountain belts, which suffered substantial tectonic denudation and late- to post-orogenic lithospheric thinning, the Urals evolved near isostasy and never departed far from equilibrium and preserved its collisional seismic patterns.

T5-12

CRUSTAL STRUCTURE OF THE FORELAND THRUST AND FAULT BELT OF THE SOUTHERN URALS FROM *URSEIS* EXPLOSIVE SEISMIC REFLECTION DATA

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A vivid image of the crustal structure of the southern Urals foreland thrust and fold belt was revealed by seismic reflection data acquired as part of Urals Seismic Experiment and Integrated Studies (URSEIS) project. This structure evolved almost entirely by the end of Paleozoic time, and was essentially stagnant since then. We aim at resolving the structure of the central Urals foreland thrust and fold belt by correlating the seismic image with the geological structure mapped at the surface. We reproduced a crustal stacked section of the western half of the URSEIS explosion data using minimal processing, mainly time domain filtering and trace dependent true amplitude recovery. Our image corroborates previous results, and provides some additional detail in the upper crust. Notably we image a steep easterly-deeping reflection that projects to the surface location of the Main Uralian fault, the main suture lineament of the Uralide orogen. The detailed shallow P- and S-wave velocity structure, modeled from P- and S-wave first arrivals, links upper crustal domains imaged on the reflection section with the geologic domains observed at the surface. We image the projection of steeply-dipping features to the surface by stacking reflected refractions. This is done by aligning the first arrivals of data shot up-dip, and stacking it in the receiver domain.

T5-13

CONTRASTING SEISMIC SIGNATURE OF ARC-CONTINENT SUTURE ZONE IN THE UPPER CRUST OF THE SOUTHERN AND MIDDLE URALS

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The comparison between vertical incidence reflection seismic data from the Middle (ESRU93,95 & 96) and the Southern Urals (URSEIS & R114) indicates that there are remarkable differences in upper reflectivity in the area of the arc and in the arc-continent suture zone. The Main Uralian fault (MUF) appears as an east dipping, weakly reflective event in the Southern Urals that seems to respond change in the reflectivity pattern between the eclogite-bearing Maksutovo Complex to the west and the Magnitogorsk volcanic arc to he east. On the contrary the MUF in the Middle Urals appears as package that upon migration transforms into two different sets of east dipping reflections: Uralian Normal Fault (MUNF) and the Main Uralian Thrust Fault (MUTF). Structurally above the MUF, the Magnitogorsk arc in the southern Urals appears as a weakly reflective unit at upper crustal levels where only discontinuous reflectors occur. Whereas the Tagil Volcanic arc, in the Middle Urals, shows well defined east and west dipping reflectivity in the upper crust that, after integration of vertical incidence, VSP and borehole data from the SG4 borehole, has been related to faults and fracture zones. After reprocessing part of the Russian R114 and URSEIS vibroseis sections and comparison corresponding ESRU93 and 95 lines, we suggest that the MUF in the Middle Urals is overprint deformation and that it does not represent the original arc-continent suture. This would imply different reflectivity patterns exhibited by the Magnitogorsk and Tagil arcs can be interpreted as variations in the tectonic evolution of the crust in the Southern and the Middle Urals. However, it is also possible that different parts of the arc are imaged (i.e., well developed forearc region in the Southern Urals versus arc in the Middle Urals). Late extension or transtension may have significantly affected the arc-continent collision in the Middle Urals, resulting in its different reflective character compared to the southern Urals.

T5-14

HIGH RESOLUTION SEISMIC IMAGING OF DEFORMATION ZONES IN SW SWEDEN

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Near linear regional ductile deformation zones are prominent features in the Sveconorwegian orogen of south-western Sweden. Many of these zones are believed to have developed during the Sveconorwegian-Grenvillian orogeny. A question of particular interest is the 3D geometry of such deformation zones north and east of Lake Vänern in the eastern part of the Sveconorwegian orogeny, including the so called "Protogine Zone" (PZ) south of Kristinehamn. In this area, which extends from the Mylonite Zone in the west to the undeformed Transscandinavian Igneous Belt (TIB) rocks in the east, modern bedrock mapping has revealed that the structures display an asymmetric fan-like configuration. A primary question is whether this fan-like structure and associated ductile deformation zones formed in a compressional or extensional tectonic regime. In order to address this question and others a 17 km long reflection seismic profile was acquired south of Kristinehamn in August 1996. Receiver spacing was 25 m and nominal shot spacing was 100 m. A charge size of 0.5 to 1.0 kg was fired in 3 m deep shotholes. The profile crosses the central axis of the surface mapped fan-like structure and deformation fabric dips about 15-40° E on the western end of it and 60-80° W on its eastern end. The seismic data show a bivergent geometry with its central axis about 8 km east of the "Protogine zone". The geological map in the scale 1:50 000 indicates the expected hinge axis to be located about 3 km further east. In spite of this discrepancy, there is good general agreement with the structure as defined by the surface geology. The image obtained by the reflection seismic experiment supports the fan-like structural interpretation from surface geology. Together with other deep seismic data set, the present seismic data support the development of the fan-like structure as a two stage deformation process. The first stage consisted of crustal thickening and stacking after 1.57 Ga, but prior to 1009-965 Ma. The second compressional stage occurred during 930-905 Ma and resulted in the development of the Sveconorwegian Frontal Deformation Zone (SFDZ), equivalent to the Grenville Front in North America. The eastern limit of major deformation in this zone is imaged on the seismic profile and projects to the surface somewhat west of where the zone is indicated by surface geology. The zone itself becomes listric at depth and appears to sole into a zone of lower crustal reflectivity below Lake Vänern suggesting that this lower crustal reflectivity developed during the Sveconorwegian orogeny.

T5-15

CALEDONIAN AND VARISCAN STRUCTURES IN SOUTHWESTERN IRELAND EXPLORED BY WIDE-ANGLE SEISMIC PROFILING AND TELESEISMIC STUDIES

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As part of the VARNET (VARiscan NETwork) project, two wide-angle seismic profiles were recorded in June 1996 in southwestern Ireland. Line A was deployed from Kinsale in the South to North County Clare. This line crosses both the Caledonian Iapetus Suture zone and the Variscan Front. Line B extends across the westernmost peninsulas of Ireland, from Roaringwater Bay in the South to the Shannon Estuary in the North. It crosses the Variscan Front near Dingle Bay. In addition, several earthquakes and a Chinese nuclear test were recorded. Wide-angle seismic modelling for line A and B describes a highly variable upper crust extending to a depth of about 15 km. The total crustal thickness is about 30 km throughout. Along both profiles the main heterogeneity in the upper crust is located near the Variscan Front. Models are compatible with thin-skinned tectonics, which terminated at the Dingle-Dungarvan Line and which incorporated thrusts involving the sedimentary and upper crustal layers. From the analysis of the residual times of two teleseismic events recorded along the line A, the probable trace of the Iapetus suture at depth has been found in the upper mantle just south of the Shannon River. Modelling indicates that the closure of the Iapetus Ocean may have involved a southward subducted slab. This talk attempts to summarise these results in order to produce a global lithospheric model of Southwestern Ireland. This region where Caledonian and Variscan structures are largely mixed is the westernmost key of the understanding of these both Palaeozoic orogens.

T5-16

ESCI: THE DEEP SEISMIC PROGRAM IN SPAIN. A REVIEW

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Deep vertical reflection profiles totalling 1350 km offshore and 450 km onshore have been acquired in Spain within the ESCI (seismic studies of the Iberian crust) program. Most relevant features of these data are summarized here. In NW Spain the ESCI-N profiles provide a crustal cross-section of the Variscan orogenic belt, the northern continental margin, the Alpine features of the Cantabrian mountains and its southern foreland, the Duero basin. The seismic results establish the thin-skinned character of the Variscan deformation onland, show the tectonic accretionary prism at the transition from the continental platform to deep sea areas of the Bay of Biscay, and reveal an important crustal thickening related to the Alpine reworking of the Cantabrian mountains. On the NE Iberian margin, a crustal transect has been completed from the southern foreland of the Pyrenees to the South Balearic Basin, across the Valencia trough. In this area, affected by successive extensional and compressional tectonics since Cenozoic times, the continental crust is thinned by a factor of 2 in about 50 km horizontal distance. In southern Spain, the ESCI profiles investigated the deep structure of the westernmost Mediterranean region, the Betic cordillera and the Alboran Sea. Marked differences are observed in crustal thickness, as well as in the reflectivity patterns at upper crustal, lower crustal and Moho levels, related to the complex evolution of the Betic-Rif orogenic system that involve episodes of extensional and lateral tectonics. Complementary wide-angle data from onshore-offshore recordings or refraction experiments onland, available in the three domains investigated, provide additional velocity-depth constraints.

T5-17

VARISCAN AND ALPINE SEISMIC SIGNATURES ON THE NORTHERN IBERIAN PENINSULA

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The seismic structure of the western prolongation of the Pyrenees along the Basque-Cantabrian Mountains has been investigated by several refraction and wide angle reflection experiments carried out in the last 7 years. The velocity-depth distributions obtained in E-W and N-S transects provide for the first time a regional 3D image of the seismic velocity structure of the crust at the Northern Iberian Peninsula. The area exhibits three-dimensional heterogeneity resulting from its long geological history through two orogenic cycles -Variscan and Alpine- that show almost perpendicular strikes. The western part of the range, toward the Variscan hinterland zones, show a crustal structure similar to that of the Variscan belt around W-Europe. Three main levels, upper, middle and lower crust with average velocities 6.0, 6.25 and 6.8 km/s are differentiated, and the total crustal thickness is 30-32 km. Some Paleozoic structures as the Cantabrian Zone basal detachment are expressed in the seismic models. Significant crustal variations appear eastward, in the central part of the Cantabrian Mountains. Most outstanding feature is the presence of a crustal root beneath the highest Cantabrian summits (Picos de Europa area) where the Moho is found at near 50 km depth. A remarkable step in Moho topography was imaged in the transition from mainland to continental platform where the continental margin Moho is situated at 30 km depth, thinning northwards. In the Basque-Cantabrian Basin area an inverted sedimentary basin and a thinner continental crust evidence the important extension occurred in this area prior to the Pyrenean collision. A prominent reactivation of the Variscan crust by Alpine deformation in the Northern margin of the Iberian Peninsula is thus constrained. The crustal seismic structure of this area reflect the complex interaction between Iberain and European plates and allows the geodynamical modelling of an active continental margin, from the tectonic inversion of the former extensional basins up to the subduction and continental collision.

T5-18

A NORTH-SOUTH CRUSTAL TRANSECT ACROSS THE NORTH IBERIAN MARGIN AND THE CANTABRIAN MOUNTAINS (NW SPAIN)

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The convergence of the Iberian plate with Eurasia during the Tertiary resulted in the partial closure of the Bay of Biscay (BB) with the development of a subduction zone, the deformation and tectonic uplift of the Cantabrian Mountains and the building of the Pyrenees in the east. A crustal transect images the structure from the Duero foreland basin to the BB's abyssal plain across the Cantabrian Mountains and the North Iberian margin. It shows Mesozoic extensional structures related to the opening of the BB and the later Alpine reworking undergone by the Variscan crust of the Cantabrian Mountains due to the N-S compression. The compression produced the reactivation of Variscan structures and the tectonic inversion of Mesozoic normal faults. Depth-converted ESCIN-2 and ESCIN-4 deep seismic reflection profiles (inland and offshore) and gravity models show the Moho rising from 32 km depth beneath the Duero Basin to 15 km in the abyssal plain, and the crust thickened to about 50 km depth beneath the Cantabrian Mountains. The most striking characteristic is that this asymmetric crustal root is not made of the Bay of Biscay's oceanic crust underthrusted to the south, but of mid and lower crust from the Iberian continental side. The root was built by the southwards indentation of the BB's crust, splitting the continental crust of Iberia, that was underthrusted towards the north. The overall crustal structure resembles that of other alpine orogens such as the Alps and specially the Pyrenees, where the Iberian plate underthrusts the European plate. Two Tertiary basins developed on both sides of the orogen: the continental Duero Basin (up to 2.5 km thick) and the deposits in the continental platform and abyssal plain (up to 5 km thick). Both were filled with materials derived from the erosion of the new reliefs generated by the uplift of the Cantabrian Mountains.

T5-19

THE TRANSITION FROM "COLD" TO "HOT" AREAS OF NORTH AMERICA AND THE LOCATION OF HIGH-SEISMICITY ZONES - REINTERPRETATION OF *EARLY RISE* SEISMIC DATA

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The long-range seismic sections of the Early Rise experiment identify a characteristic delay of refractions from below the Lehmann discontinuity on most profiles. The delay is identified at the far end of the lines and coincides with a transition from a continuous, homogeneous first arrivals to seismic phases, which are scattered in traveltime and amplitude. The change in character of the seismic waves is similar to the characteristic change at the 8° discontinuity at ~100 km depth. From here a low-velocity zone extends to the Lehmann discontinuity at ~150 km in "cold", tectonically stable areas whereas it has been found to extend to near the 400 km discontinuity in "hot", tectonically active areas. The Early Rise sections were acquired with a common shot point in Lake Superior, which is situated within the "cold" North American craton. Ray-tracing modelling shows that the delay in Lehmann refractions at depth occurs near the transition from the plains to mountainous areas on the west-striking Early Rise lines. Hence, it corresponds to the transition from the central N. American area of high average upper mantle velocity to the western area of low average velocity. Therefore, we interpret the cause of the characteristic delay to be the transition between "cold" and "hot" areas. Modelling shows that this transition, at > 150 km depth, occurs over a less than 100 km wide horisontal zone. Coincidence with zones of crustal earthquakes indicates that such deep transition zones may have strong effects on the shallow, local tectonics.

T5-20

THE *DEEP PROBE* EXPERIMENT CONTINENT-SCALE ACTIVE-SOURCE SEISMIC PROFILING

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The 1995 Deep Probe experiment was an active source seismic investigation along a N-S line extending from southern New Mexico, USA, to Great Slave Lake, Canada. The results include a 2600-kn 150km deep 2-D velocity model of crustal and upper mantle structure. Three unique crustal structures are observed along the line, with abrupt changes that lie close to and Proterozoic aged sutures rather than present-day physiographic boundaries. The crustal structure is largely controlled by events before 1.5 Ga despite more recent episodes of tectonism. The Archean Hearne province in Alberta has a mean crustal thickness of 35-40 km with a simple vertical gradient in seismic velocity through the crust. The Archean Wyoming province in Wyoming and Montana has crustal thickness of 50-55 km with the lowermost 25 km of the crust consisting of a distinct layer with seismic velocities of 7.0-7.3 km/s. The Proterozoic accreted terranes of the Colorado Plateau have a crustal thickness of 40-45 km, and can be described using a simple vertical gradient. A major change is seen also in upper mantle structure. The Colorado Plateau is underlain by mantle with seismic velocities of 7.9-8.0 km/s and a P-wave low velocity zone centered at 75 km deep and 45 km thick, similar but more extensive than that beneath the western edge of the Colorado Plateau, an equivalent to that seen beneath the Gulf of California. In contrast, the Archean terranes are underlain by mantle that is typically faster (up to 8.1-8.2 km/s), with positive velocity gradients. The difference between these regimes is seen clearly in arrivals recorded from a shotpoint in southern Wyoming implying that the changes in both crustal and upper mantle structure occur over less than 250 km.

T5-21

LITHOSPHERIC STRUCTURE OF THE SOUTHERN HEARNE PROVINCE, CANADIAN SHIELD: A PALEOPROTEROZOIC PYRENEES?

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The Vulcan structure is a major Paleoproterozoic tectonic boundary between the Loverna Block and Medicine Hat Block, Archean crustal domains that are buried beneath the Western Canada Sedimentary Basin. It is characterized by prominent east-trending gravity and magnetic anomalies, more than 350 km in length, that cut across the potential-field fabric of southern Alberta at a high angle. Three decades ago, the Vulcan structure was the target of one of the first deep-crustal seismic profiles and it has since been variously interpreted as a failed Proterozoic rift, an intraplate collisional zone, and a largely amagmatic suture between the Wyoming and Hearne Provinces of the Laurentian craton. Recent Lithoprobe seismic-reflection profiles, combined with new, coincident gravity data, provide the basis for a revised model of the lithospheric architecture for this region. We interpret the Vulcan structure as the relatively narrow (40-70 km) axial zone of a continent-continent collisional belt, similar in dimensions and geophysical characteristics to the Pyrenees. The seismic images indicate delamination of the lower crust of both blocks, and underthrusting of the Loverna Block lower crust beneath the Medicine Hat Block. Prominent gravity highs on the flanks of the structure are modeled as mafic material that was partly exhumed to mid-crustal depths during the collision. The Vulcan structure is also postulated to mark the northern boundary of a persistent paleogeographic high known as Montania. To test whether differences in lithospheric buoyancy across the Vulcan structure is expressed in terms of mantle reflectivity, the seismic program included two mutually perpendicular profiles recorded to 110 s two-way time. Preliminary processing of the extended vibroseis recordings confirms the polarity of the orogen, but has not yielded evidence for anomalous reflectivity in the mantle.

T5-22

S-N-O-R-C-L-E

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Seismic reflection profiling of the Precambrian lithosphere in northwestern Canada (LITHOPROBE has produced images of delamination structures (tectonic wedges) at crustal scale (to about 30 km depth) and, for the first time, at lithospheric scale (to about 100 km depth). It has further delineated subcrustal structures that were likely caused by imbrication of lithosphere. These features are delineated along a transect that begins in the Precambrian Slave Province, where the oldest known rocks (> 4.0 Ga) are found, crosses a Paleoproterozoic orogen (Wopmay orogen, ca. 2.1-1.84 Ga), and ends near the eastern edge of the Mesozoic-Cenozoic northern Canadian Cordillera. This, the first phase of the Slave-NORthern Cordillera Lithospheric Evolution (SNORCLE) transect, addresses accretionary processes Archean and Proterozoic assembly of northwestern North America. The final phase a profiling in late 1998 or 1999 will extend the profile across the northern Cordillera and will link to the U. S. ACCRETE transect in the Pacific ocean near southern Alaska to complete a ca. 2000 km transect from the oldest rocks of an Archean craton to the modern Pacific ocean.

T5-23

ACCRETIONARY TECTONICS IN THE LATE ARCHEAN? FIRST RESULTS FROM THE *LITHOPROBE* WESTERN SUPERIOR TRANSECT

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The Superior Province of North America constitutes the world's largest block of preserved Archean lithosphere, and thus provides an ideal location for studying Archean lithospheric evolution. A model of modern tectonic terrane accretion has been proposed for the western Superior Province in NW Ontario in which oceanic crust, island arcs, sedimentary prisms and continental fragments were accreted successively against the southern margin of an old (> 3.0 Ga) cratonic nucleus during ca. 2.7 Ga orogeny. In the fall of 1997, LITHOPROBE acquired 800 km of 32 s vibroseis seismic reflection data along a N-S corridor across the Western Superior Transect area. Crustal reflectivity is prominent along the entire profile with the reflection Moho gradually increasing in depth from 12 to 14 s moving southward away from the cratonic nucleus. The cratonic nucleus is characterized by S-dipping reflections that can be traced from the near surface to the lower crust where they appear to be truncated by N-dipping reflections along the southern boundary with the "accreted terranes". N-dipping reflectivity dominates within the zone of accreted terranes, with shallowly N-dipping reflections observed within the lower crust and possibly into the uppermost mantle. These preliminary observations do not contradict proposed models of Archean accretionary orogenesis for the western Superior Province.

T5-24

EPIROGENY, FLEXURE AND FORMATION OF CRATONIC ARCHES: RESULTS OF *LITHOPROBE* REGIONAL SEISMIC PROFILES IN THE WESTERN CANADA SEDIMENTARY BASIN

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As part of Canada's ongoing Lithoprobe project aimed at exploration of the crust and upper mantle beneath North America, 2000 km of 2D seismic reflection profiles have been recorded in western Canada in three separate acquisition corridors. The Central Alberta Transect (CAT), the first of the three experiments, was recorded in 1992 and was followed by the Peace River Arch Industry Seismic Experiment (PRAISE) in 1994, and the Southern Alberta Lithospheric Transect (or SALT) in 1995. To provide a basin-scale perspective, a nearly continuous 1500-km composite line has been constructed by concatenating individual profiles. Because each of the original profiles had been processed to a different structural datum, the data have been corrected to a common floating datum with smoothly varying replacement velocities. Further reprocessing of these data has been undertaken to attenuate strong multiples that obscure tectonic relationships in the uppermost basement. Display of these data using extreme vertical exaggeration emphasizes subtle stratigraphic relationships, such as onlap and pinchouts, that occur throughout the basin. At this scale, two cratonic arches, the Peace River Arch and the Sweetgrass Arch, stand out clearly in the composite section as paleogeographic highs during the late Devonian. The origin of these features, which are representative of cratonic arches throughout North America, remains contentious. Surprisingly few instances of basement reactivation are evident, but basement downwarp associated with Cretaceous crustal loading west of the transect during the Laramide orogeny appears to be locally controlled by faulting.

T5-25

3-D CRUSTAL GEOMETRY AND TECTONIC EVOLUTION OF THE ARCHEAN MEDICINE HAT BLOCK, WESTERN CANADIAN SHIELD

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The Archean Medicine Hat Block (MHB), part of the southern Alberta crust, preserves a complex history of compressional deformation and tectonism as revealed in deep-reflection seismic data, potential-field data, and time-structure maps. MHB is characterized by NW-SE and N-S magnetic trends that are truncated to the north by the Vulcan structure and to the southeast by the Great Falls Tectonic Zone. MHB is an entirely subsurface feature and is composed mainly of granitic gneisses that are buried beneath Western Canada Sedimentary Basin cover. The Lithoprobe SALT deep-reflection seismic dataset includes a 500-km regional composite section of migrated and coherency filtered crustal data, reaching 18 s twt (~59 km depth). Major characteristics of the MHB crustal morphology include: (1) Upper to mid-crustal dipping reflections throughout most of the profile overlying (2) horizontal to sub-horizontal lower crustal reflections. The upper to mid-crustal dipping reflections are interpreted to represent a series of imbricate thrust stacks. These are in turn divided into two distinct zones according to the time-structure maps. The upper zone consists of prominently W-dipping reflections, whereas the lower zone displays SW-dipping reflections. In addition, the magnetic trends appear to coincide with a change in crustal reflection fabrics. Reflection Moho is diffuse at around 15.0 s twt and may act as a regional detachment surface based on the observation that listric reflections in the lower crust flatten into it. The detachment displays a flat-ramp-flat geometry that truncates horizontal to sub-horizontal reflections. This Precambrian crustal-scale thrust ramp may have formed during a contractional event causing significant shortening of the Archean crust. A region of probable crustal thickening may represent crust that was underthrust beneath the MHB crust during Proterozoic time.

T5-26

P-WAVE VELOCITY IMAGE OF THE TRANS-HUDSON OROGEN FROM REFRACTION DATA

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The growth and evolution of the subcrustal lithosphere during a continent-continent collision process is poorly understood. Tectonic evolution of the North-American continent includes the Early-Proterozoic collision of two Archean continents. These two Archean cratons are welded together by an orogenic belt, known as the Trans-Hudson Orogen (THO), exposed in northern Saskatchewan and Manitoba. The lack of significant tectonic activity in the area since the Proterozoic times kept the remnants of the collisional processes well-preserved in the lithosphere. As part of the LITHOPROBE program, three long-range seismic refraction profiles were deployed across the THO to investigate the velocity structure of the collisional zone. Analysis of the data revealed significant velocity anomalies in the mantle, beneath the central region of the orogen. These velocity variations seem to be caused by a well defined anisotropic region, located near the base of the crust, in the mantle. Orientation and location of the anomalous mantle zone suggest that it may represent a preserved mantle suture structure, that joins two Archean cratons. Above the anomalous mantle region crustal velocities are also variable. However, these crustal velocity anomalies cannot be correlated to the recognized geological terranes. It is plausible that these velocity anomalies reflect distinct thermo-tectonic evolutional history of geological units, what has already been suspected on the basis of surface geological data.

T5-27

TOWARDS A TRANSECT OF THE NORTH AMERICAN LITHOSPHERE

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LITHOPROBE, Canada's national geoscience research project, has acquired more than 10,000 km of land-based deep crustal seismic reflection data from Vancouver Island to Newfoundland during the past 15 years. As part of its multidisciplinary scientific program, an additional 6350 km of marine-based data were acquired west of Vancouver Island, in the Great Lakes, in the Gulf of St. Lawrence, in Ungava Bay, east of Labrador and on Canada's Atlantic margin. A subset of these data are compiled into a transect that traverses the North American continent from the active Juan de Fuca Ridge in the Pacific Ocean, across the southern Canadian Cordillera, the craton underlying the Western Canada Sedimentary Basin, the exposed Precambrian shield of central Canada, the southern Superior Province of Ontario and Quebec, the Grenville Province, and the Appalachians of eastern Canada to the Mesozoic continental margin of the Atlantic Ocean. The 6500-km long composite reflection section provides lithospheric structure over an unprecedented length scale and establishes a framework for compiling and analysing many of the LITHOPROBE geological and geophysical data

T5-28

DEEP SEISMIC INVESTIGATIONS ON ZAPOLYARNY - HEIS GEOTRAVERSE (BARENTS SEA)

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In 1995 geophysical investigations on the 700 km southern part of the AP-1 geotraverse across the Barentsevomorskaya plate were completed. The profile was directed from the super-deep SG-3 well at the town of Zapolarny (Kola peninsula) to the base Heis-1 well on Franz-Joseph Land. Seismic researches included Deep Seismic Soundings (DSS) as well as CDP profiling with varying source-receiver (s-r) distances. Powerful air-guns (up to 80 litres) allowed for recording of long Time-Distance curves (up to 150-280 km) and steady registering of intensive Moho reflections. Dense enough observation system was used with soundings distance 5 - 20 km and shot interval 250 m, which resulted in reliable phase correlation and identification of different waves. On-see shots responses were also recorded by on-land stations for correlation of seismic horizons and determining geological structure in the transit zone. A total of 135,000 r-s observations was recorded. The interpretation of processed seismic records included computer-aided arrivals picking and solving inverse kinematic problems using two approaches: (i) inversion of refracted (head) and reflected T-D curves based on the multilayer model with laterally varying layer velocities and (ii) seismic tomography in the layered gradient model. Continuous Moho image was built up on the dynamic time-section. The wave analysis shows the domination of near- (for Moho) and super-critical reflections while main refractors are located in the cover and at the basement. DSS allowed for determining the Barentsevomorskaya plate main geological structures practically across the whole crust thickness. The outmost deep traced horizon is Moho positioned at the 35 to 40 km depth while the sedimentary cover thickness varies from 0 to 14-16 km when moving from south to north along the profile.

THEME 6: Seismic reflection applications to natural resources and environment

T6-01

DEEP SEISMIC IMAGING OF THE HYDROTHERMAL PALEOFIELDS IN FRENCH MASSIF CENTRAL - *GEOFRANCE 3D* PROGRAM

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A newly acquired two deep (Laurieras and Argentat) and one high resolution (Laurieras) reflection seismic profiles are carried out in Limousin region (French Massif Central). These profiles are respectively 40, 50 and 10 km long. They cut metallogenic provinces composed by a sequence of instantaneous events that occured over 60 Ma in the tectonic history of the Variscan belt and which are marked by successive emplacements of W, Au, Sb and U mineralization between 300 and 270 Ma. The objective of the project was (i) to image the anastomosing geometry of the hydrothermal paleofields and hydrothermal cells and (ii) to characterize the traps and sources relationships toward the crust. The ten kilometers high resolution (HR) seismic profile located over Laurieras gold mine is recorded using a 96 channels array with 25 m spacing. The deep reflection seismic array is composed of 180 channels with 55 m spacing. Small explosive charges in shallow boreholes are used as the sources every 50 m for the HR profile whereas 15 kg of explosives charges are buried in 20 m boreholes for the deep reflection profiles. The data are recorded on a Polyseis telemetric system, using a symmetric split-spread configuration and end-on geometry at the ends to give better coverage, which is around 24-fold for the high resolution and 20-fold for the deep seismic profiles.

T6-02

EXPERIENCES FROM SHALLOW REFLECTION SEISMICS OVER GRANITIC ROCKS IN SWEDEN

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The Department of Geophysics at Uppsala University has been carrying out seismic reflection experiments since 1984. Most of these experiments have been on a crustal scale (50 or 100 m spacing between geophones), but a number of these have also been high resolution surveys (5 or 10 m spacing between geophones) where the targets have been in the upper kilometer of the Earth. In those areas where we have focused on the more shallow crust we have often had access to boreholes for control of our interpretations. Results from five areas in Sweden, all of which are located in granitic rock type environments, are briefly reviewed. Three of the surveys were carried out with station spacings of 5 or 10 m (Dala Sandstone - Juhlin et al., 1991; Finnsjön - Juhlin, 1995; Ävrö - Juhlin & Palm, 1997) while the other two surveys were of a more regional character (Siljan Ring - Juhlin, 1990; SW shear zones in Värmland, Juhlin et al., 1997). These latter two have been included in this review since they provide good images on conditions at depths of less than 2 km. In granitic rock type environments in Sweden two predominant sources to seismic reflections are found, dolerite intrusions and fracture zones. Dolerites were found directly in the deep wells in the Siljan impact structure and were inferred to be present from the seismic data in the Dala Sandstone area. Similar sub-horizontal reflections have also been found below the Bothnian Sea and have also there been interpreted as having their origin from dolerite sills (Babel Working Group, 1991). The dolerites represent high impedance layers in the host granitic rock and are sub-horizontal to gentle dipping. The fracture zones contain free water and, thus, represent low impedance layers in the granitic host rocks. They can be sub-horizontal to steeply dipping and are generally less laterally continuous than the dolerites. Polarity analyses of the seismic data is a method to differentiate between dolerites and fracture zones in granitic rocks. Several factors determine how shallow features in the crust can be imaged with the seismic reflection method. Some of the most important acquisition parameters are station and source spacing, number of channels, and source and geophone coupling. Important processing parameters are static corrections, spectral balancing and velocity filtering. The ability to differentiate direct S-waves from P-wave arrivals in the first 100 ms determines to a large extent if the upper 100 ms can be imaged.

T6-03

ENHANCED IMAGING OF THE GUICHON CREEK BATHOLITH, BC, CANADA, TO DELINEATE STRUCTURES HOSTING PORPHYRY COPPER DEPOSITS

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The Guichon Creek batholith, located in south-central British Columbia, contains several large, low-grade copper deposits of considerable economic importance. It is situated within the Quesnellia terrane of the Intermontane superterrane and was emplaced in the early Jurrasic. The batholith is composed of several concentric phases which have contacts that may be sharp locally but are generally gradational. The Guichon batholith and its surrounding region have been well mapped from the perspective of the surface geology; however little information on the subsurface features of the batholith is available. Previous interpretation of gravity data suggests a mushroom-shaped structure for the batholith. In 1988, LITHOPROBE's Southern Cordillera transect reflection Line 88-11 was recorded across the batholith to 18 s two-way-travel time (TWT). Processing by an industry contractor primarily focussed on delineating crustal scale features, and hence was not optimal for enhancing the uppermost crust (~10 km). Interpretations of the data in terms of crustal structure and related tectonics have been published.A closer look at the data above 4 s reveals weakly coherent east-dipping reflections on the west side and west-dipping reflections on the east. Do these correspond to the base of the batholith? Can any of the faults mapped at the surface be identified on the sections? These are some of the questions that can be answered with an improved seismic image of the upper crust. Additional quantitative modeling of gravity and aeromagnetic data provides 2.5D (profile sense) and 3-D information on the basic shape and internal structure of the batholith. This paper presents reprocessed results from the western end of Line 88-11 across the Guichon Creek batholith from 0-6 s TWT, with particular emphasis on applications of signal enhancement techniques (e.g.,pattern recognition methods, refraction statics, dip moveout corrections) and correlation of the improved subsurface images with the geological environment associated with porphyry copper deposits. Low near-surface velocities correlate well with the phases of the batholith hosting the major copper deposits which structurally lie in faulted and brecciated regions. Results indicate that although the top 1.5 km cannot be imaged by the regional scale seismic reflection data, near-surface velocities can be correlated to the surface geology where the major copper deposits lie. Also modeling of high resolution aeromagnetic data helps in better defining the near surface. The reprocessed seismic section gives a clearer picture of the batholith, its edges, the various concentric phases and the stem.

T6-04

THE VERY SHALLOW FRONTAL STRUCTURE OF ACTIVE KAMISHIRO THRUST REVEALED BY SEISMIC REFLECTION PROFILING, "*GEO-SLICER*" AND DRILLING

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The Itoigawa-Shizuoka Tectonic Line (ISTL) is one of the most important tectonic lines which divides NE Japan and SW Japan and shows high averaged slip rate of several mm/yr. The detailed frontal structure of the Kamishiro thrust, northern segment of ISTL, was investigated by high resolution P-wave seismic reflection profiling and Geo-slicer. The Geo-slicer is a new technique to obtain a long and wide unconsolidated Quaternary sediment slab. Using the Geo-slicer and drilling, the detailed structure of thrust front in size of 20-m (depth) and 30-m (width) was clearly demonstrated. A high resolution P-wave seismic reflection profiling was performed. 30 to 250 Hz sweep signals by mini-vib (IVI) were recorded by 40 Hz geophones at 1 m spacing. Both techniques successfully produced the detailed image of the thrust front up to 100 m in depth. The thrust shows branching near the surface and the main thrust forms a blind fault at 30-m in depth. The averaged slip rate of shallower branching fault, ca.1.5 mm/yr, represents the minimum value of the total fault system.

T6-05

GROWTH FAULT-BEND FOLDING ALONG THE BOUNDARY BETWEEN EURASIA AND NORTH AMERICAN PLATES IN THE AXIAL ZONE OF HOKKAIDO, JAPAN

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Due to the contraction of Eurasian and North American / Okhotsk plates and west ward motion of the Chishima fore arc sliver, the NS trending fold and thrust belt was formed in the western part of Hokkaido axial zone. The west-ward migration of thrusting continued since mid-Tertiary. To reveal the activity of the thrusting in late Quaternary, seismic reflection profiling was undertaken across the estimated blind thrust in Yufutsu, Hokkaido. The seismic source was a Mini-vibrator truck at 10-m intervals. The signal was recorded by a 10-m group interval of 30-Hz geophones. The structure of growth fault-bend fold is clearly demonstrated by the seismic reflection profile. As the sediments at about 100 m (0.1 sec TWTT) in depth involve in growth strata and the top surface of the pyroclastic flow deposits erupted at 40 ka shows gentle folding, the thrusting produced this growth fault-bend fold continued during late Quaternary. Thus, it is highly probable that the boundary between Eurasian and North American plates is still located along the axial zone of Hokkaido and has not shifted along the east coast of the Japan Sea.

T6-06

BASIN-WARD MIGRATION OF THRUSTING AND ACTIVE FAULT-PROPAGATION FOLDING IN THE SHINJO BASIN, NE JAPAN

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The active folding and late Quaternary basin-ward migration of thrusting of fault system in the eastern Shinjo Basin, central northern Honshu, is recorded in the morphotectonic features and geological successions. To reveal its mechanisms, the sesimic reflection profiling was undertaken across the NS-trending fault system in the eastern Shinjo Basin. The seismic source was a Mini-vibrator truck, with 10 seconds of 10-80 Hz signals at 30 m intervals. The signal was recorded with 120 and 180 channels by a 15-m group interval of 10-Hz geophones. The seismic reflection profile reveals that the active folding has been formed by the movement of sub-horizontal ductile detachment in the Miocene mudstone which deposited during the post back-arc opening stage. The basin-ward migration of thrusting was due to the basin-ward propagation of sub-horizontal thrust. Thus the seismogenic fault need to asses is located far east of the surface active fault, just below the Backbone Range.

T6-07

CRUSTAL REFLECTIVITY SUTDIES OF DIAMOND FIELDS OF THE SIBERIAN CRATON AND OIL REGIONS OF THE RUSSIAN PLATFORM

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The CDP data, are considered and interpreted for the seismic profiles crossed diamond deposit fields and kimberlite regions of the Siberian Craton and the South-Tatar oil swell in the Russian Platform. Both regions were investigated in the framework of the GEON project "Studies of faults and tectonic activity zones on basis of thermodynamic model of deep fault formation in mineral deposit fields of Russia" The seismic data were collected with record lengths of 16-20 sec, 48-50 folding and with explosions as sources. In the upper, middle and lower crust of the both anomalous reflectivity zones (bright spots) were revealed. Special studies amplitude and travel-time characteristics of these reflections and their distribution relatively to the deposit fields showed a correlation between the reflectivity zones at different depth levels and deposit locations. The depth images of the crust and upper mantle, were interpreted in the frame of the tectonic-physical conception. The latter based on fractal conception of self-organization of geological systems and considers vertical zoned structures of tectonic transformation of crustal rocks as a result of deep fracturing.

T6-08

2D SEISMIC SURVEY ON JOHNSONS GLACIER, LIVINGSTON ISLAND (ANTARTICA)

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The Department of Glaciology from University of Barcelona, in collaboration with I.A.G. and I.C.C., has developed a seismic survey on Johnsons Glacier during 1997-1998 Antarctica summer. This survey has been carried out inside the Antarctic Research Projects of the Spanish National Antarctic Plan. 2D reflection seismic data were recorded along two lines (2085 and 895m long) in order to determine the glacier basin geometry for its subsequent modelation. In this way, it is possible to compare this information with field observations, as ice surface velocities, mass balance, ice thickness variations and ice fissure locations. This presentation deals with features of this area, characterization of raw shot gathers, processing (determined by strong ground-roll and low fold) as well as the main difficulties found during field work and processing stages.

THEME 7: Seismic techniques: new developments

T7-01

TRAVELTIME AND FULL WAVEFORM INVERSION OF LONG OFFSET MARINE SEISMIC DATA

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We present a strategy for handling a regional marine seismic survey in order to obtain a well constrained estimation of the macro-velocity model nature of the region. The dataset is a 200 km long 2D profile across the Voring basin, offshore Norway; from which we have analysed a 50 km section from the second quarter of the line. The data were acquired using a single streamer recording to nearly 8 km offsets, with 25 m shot and 12.5 m receiver spacing respectively. The acquisition of longer offsets presents new processing challenges in handling the data since the assumption of hyperbolic moveout used in conventional processing based upon nmo analysis begins to break down with increased offset. However these longer offsets, if handled correctly, provide a better opportunity to constrain the velocities as opposed to the impedance contrasts (reflectors) that near offset data image. Our dataset shares manysimilarities with the Synthetic Aperture Profiles (SAP's) that have been acquired for crustal-scale sedimentary basin investigations in regions such as the Atlantic margin. We therefore do not follow conventional processing steps for streamer data to extract a velocity model, but instead implement an approach more akin to tomographic techniques used to handle wide-angle data. Processing techniques for handling wide-angle data have historically been underdeveloped; routinely only the traveltimes (and maybe the amplitudes) of the most prominent arrivals (often only the first arrivals) are used. In this dataset we were able to identify, and extract traveltimes from several key events over a large range of offsets using an automatic picking algorithm on shot gathers spaced every 500 m along the line. This large store of picks is coupled with a traveltime algorithm capable of inverting simultaneously for interfaces and velocities using near and far offset constraints. From this we then undertake preliminary investigations using a full 2D wavefield inversion algorithm for long offsets developed at Cambridge. A comparison of the velocity models extracted by these approaches is made with a model produced by moreconventional near offset nmo analysis.

T7-02

WAVEFORM AND VECTORIZED STACKING OF DIRECTIONALLY SEPARATED WAVEFIELD, MIDDLE URALS, RUSSIA

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Two forms of seismic sections presentations - traditional waveform and less traditional line-drawing form - represent two branches of seismic processing. Both of them have there advantages and disadvantages. Waveform processing has wider range of applications especially in pre-stack processing. Automatic picking of events, line drawing, i.e. vectorization of wavefield has some advantages on the stage of stacking and recognition of sources of seismic events. From the point of view of imaging these two approaches can be related as raster and vector graphics. The first one gives more detailed and smooth image, the second one allow much wider range of scaling and simple separation or excluding specified events (e.g. noise, artifacts). The best result gives combination of these approaches. Simplified 3D or 2.5D observations (with crossed line patterns) in the Middle Urals during both small scale and detailed experiments allow to separate reflection events coming from vertical plane of profile and from out of the plane of section, to make sections not only in vertical plane but also in inclined planes. For example, in the vicinity of the SG-4 Deep Borehole after preliminary gravity data analysis that gives direct sign for seismic localization of sienite intrusions aside of the vertical plane of the profile in the field of fault zones.

T7-03

SEISMIC IMAGES OF THE CRUST FROM THE WIDE ANGLE REFLECTION MIGRATION ALONG "*BALTIC SEA*" PROFILE

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A new technique for depth migration was applied to wide-angle reflection data of the marine profile BALTIC SEA in the southern part of the Baltic Shield. The profile carried out by the Institute of Oceanology, Moscow, with seismic bottom stations and with airguns (Ostrovsky et al.,1994). The migration was based on a joint explotation of time and wave field continuation. The field was calculated by the finite-difference method on special grids. A special transformation of the grids was used to get a stable solution: the grid lines were curved and followed the rays and wave fronts calculated for a given 2-D velocity model. The migration images show some new specific features of the shield crust. In the southern part of the profile a reflective layer is imaged at a depth of 15-25 km, and the Moho is traced as a sharp boundary at a depth of 45 km. In the middle part the crust-mantle transition zone is characterized with a strong dipping of the Moho down to 55 km and with thick reflective zone in the lower crust. In the northern part, a Crystal transparent zone is revealed down to depth of 20 km, and the Moho uplifts up to 40 km. This zone is interpreted as an old rift.

T7-04

3-D CRUSTAL VELOCITY TOMOGRAPHY IN THE CENTRE AND SOUTH OF THE KOREAN PENINSULA

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A new technique of simultaneous inversion for 3-D seismic velocity structure by using direct, reflected, refracted waves is applied to the centre and south of the Korean Peninsula. Pg, Sg, Pm, Sm, Pn, Sn arrival time of 76 events with 959 seismic rays recorded by 33 stations are inverted for locations and crustal structure. 5 (along the latitude) X 6 (along the longitude) X 8 (along the depth, 4 km each layer) blocks for the centre, 6 X 6 X 8 blocks for the south were inverted. 3-D seismic crustal velocity tomography including 8 sections from surface to Moho, 13 profiles along latitude and longitude for centre, 10 profiles for the south, Moho depth distribution were got. The results demonstrate: (1). The average velocities of sediment is 5.15 km/s and 5.0 for the centre and south respectively, thickness are 3-4 km, the velocities of basement are 6.15 km/s for the centre and 6.11 km/s for the south; (2). The velocities fluctuate strongly in the upper crust. The velocity distribution of lower crust under Conrad appears basically horizontal; (3) The average depth of Moho is 29.8 km with 7.97 km/s of velocity for the centre, 30.4 km with 8.01 km/s of velocity for the south; (4). The remarkable crustal velocity differences among Pyongnam Basin, Kyonggi Massif, Orkchon Zone, Ryongnam Massif, Kyoungsar and Pohang Basin can be found. (5). The different crustal features of ocean and crust are obvious; (6). Some deep index of Chugaryong Fault Zone, Yangsang Fault Zone can be found; (7). There is a lower velocity body corresponding to the Hongsong earthquake of M=7.0 in 1594.

T7-05

DEKORP'S DEEP SEISMIC SURVEYS IN THE INTERNET

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DEKORP (DEutsches KOntinentales Reflexionsseismisches Programm) is the German deep continental seismic reflection program funded by the Federal Ministry of Education, Science and Technology since 1983. The strategy in the first 10 years of seismic probing focussed mainly on an investigation of Germany's crustal architecture which had been mainly formed by the Variscan orogeny with some later overprinting. During the last 5 years, the DEKORP project was managed by the GeoForschungsZentrum Potsdam (Germany). With that, the aims have also been changed by focussing now on specific geodynamic questions leading to an internationalization with respect to localities and partners. During DEKORP's numerous campaigns more than 4500 profile kilometers (2D) and 350 square kilometers (3D), in summary more than 240 Gigabyte, of seismic field data were collected. By this, a large, unique, and valuable lithospheric database has been created. At the GFZ Potsdam a working group was established in 1998 to prepare, archive, and protect all these data on modern storage media (the seismics was originally recorded on common 1/2 inch magnetic tapes) and to provide them to the public and scientific community. For an easy and clear administration of the complex data structures a public-domain relational UNIX database with the ability of WWW-applications is under construction to give the opportunity of an online-access to all interested geoscientists and others. Seismic data in different processing stages (from the field tape to the final line-drawing) will be available for all collected surveys in trace- as well as in graphical format together with related informations such as coordinate tables, maps, geological interpretations, corresponding literature, etc. The prime aim is not to create a pure data cementery which no one likes to use, but to provide a catalogue-like structure with download-facility using the modern information technologies that are already or in the near future at hand.

T7-06

HIGH RESOLUTION RE-PROCESSING OF THE NEAR-SURFACE REFLECTION DATA ACQUIRED OVER THE CHICXULUB IMPACT CRATER

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Four marine deep reflection profiles were collected over the Chicxulub impact structure in 1996. As part of the acquisition plan, the front 2 km of the hydrophone cable were sampled with a 12.5 m group spacing with the intention that these data would be reprocessed at the maximum resolution to help interpret the pre-impact and post-impact sediments, the crater floor topography, and structure of the crater rim. The data were subsequently processed through a hydrocarbon-type processing sequence that included DMO and post-stack migration. Unusually for marine data, it was found that residual statics were beneficial over the offshore extension of the cenote ring seen on-shore where significant karsting had disrupted the near surface velocity structure. The result shows that this acquisition and processing strategy has given a significantly better result for the specified targets down to 4 s two-way travel-time (approx. 8 km) than the more typically processed deep reflection profile. The resulting post-stack depth images are shown to be consistent with results obtained by pre-stack depth migration to within a wavelength (approx. 100 m) over most of the depth range.

T7-07

PARAMETERIZATION OF REFLECTED WAVEFIELD BY DATA DECOMPOSITION: AN EXAMPLE FROM CRUSTAL REFLECTION PROFILING

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Interpretation of deep crustal reflection seismic data where drill hole data and surface outcrop constraints are absent is restricted to classifying and quantifying reflectivity patterns. This is made possible with the advent of recently-developed data decomposition techniques such as seismic skeletonization, wavelet-transformation and data-intrinsic decomposition. Each one of these allows parameterization of the reflected wavefield, thus providing methods to analyze reflectivity patterns. In seismic skeletonization, coherent events and their attributes are identified and stored in a relational data base for statistical analyses. Wavelet-transform and data-intrinsic decomposition techniques are the basis for time-frequency distribution analyses. Together, all of these provide mechanisms to enhance normal geometry-based interpretation of reflectivity patterns. This is illustrated with field and processed data from Corridor 1 of the Slave-Northern Cordillera Lithospheric Evolution (SNORCLE) transect of the Lithoprobe project.

T7-08

PRESTACK TIME MIGRATION WITH RELATIVE-AMPLITUDE PRESERVATION: RESULTS FROM THE *LITHOPROBE SNORCLE* TRANSECT, NORTHWESTERN CANADA

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A processing flow for crustal seismic reflection data is presented that attempts to preserve relative reflection strength over a wide range of dips and depths. Currently, the approach adopted by LITHOPROBE includes an AGC applied to input traces, stacking of common midpoint (CMP) gathers without dip moveout (DMO), poststack migration, and coherency filtering prior to display and interpretation. This processing flow, although effective in imaging the structural relationships revealed by continuity and patterns of reflections, does not preserve relative amplitude.The new processing flow hinges on equivalent offset migration (EOM), a fast method for prestack time migration of reflection seismic data. The method is divided into two steps: (1) a gathering process that forms common scatterpoint (CSP) gathers without requiring DMO; and (2) a simplified Kirchhoff migration which is performed on the CSP gathers. Relative amplitude is preserved by careful preprocessing of input traces, followed by theoretically correct scaling and filtering factors in the prestack migration. The high fold of the prestack migrated output traces provides good signal to noise ratio that gives comparable results to coherency filtering. The new flow is tested on a portion of the LITHOPROBE SNORCLE transect Line 1, and compared to the current approach.

T7-09

CRUSTAL VELOCITY DETERMINATION USING EXPANDING SPREAD PROFILES

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Four vibroseis expanding spread profiles (ESP) were collected in the 1991 LITHOPROBE Trans-Hudson Orogen (THO) data acquisition program to obtain more detailed and accurate velocity structure. These profiles, with a maximum offset of 18 km, were centered on areas where prominent crustal reflectivity was detected by the regional vibroseis survey. The small source stepout distance (100 m) generated high-fold (>30) data. Extensive modeling was carried out to estimate the offset range within which each traveltime approximation and velocity analysis technique may be implemented. The results reveal that velocity estimation becomes more robust and accurate when crustal seismic surveys utilize longer offsets than commonly used. These larger source-receiver separations, however, must be generally limited to offset/depth ratios not exceeding 1.5 when conventional velocity analysis techniques, based on the hyperbolic moveout assumptions, are implemented. Besides the semblance method, two velocity estimators adapted to crustal studies, namely the covariance and the τ-p techniques, were tried. The former yielded the highest resolution followed by the semblance and the τ-p methods. Resolution of the semblance estimator for a maximum offset of 36 km is equal to that of the covariance method with a corresponding offset of 18 km for mid-crustal reflectors. The advantages provided by the long-offset data acquisition include increased S/N ratio and a greater number of traces with sufficiently large moveouts which improved velocity resolution, especially below mid-crustal depths. To achieve similar advantages in a regional crustal reflection survey would require the adoption of longer spread lengths than those presently implemented in standard data acquisition procedures.

T7-10

SEISMIC IMAGE QUALITY BENEATH STRONG SCATTERING STRUCTURES: NUMERICAL SIMULATIONS.

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Spatial variations in seismic velocity produce anomalous zones which lead to seismic wave scattering. Hence it is important to understand how scattering can influence our ability to image the lithosphere. To this end, we analyse finite difference synthetic data for different two layer models; the top layer is statistically defined based on super-deep borehole data. We consider models with a range of velocity fluctuations based on the borehole logs. The data were processed as real data and the final stacked and migrated section were analysed, using a crosscorrelation method to determine the degree of multiple scattering contamination. We find that: a) multiple scattering and associated coda formation interfere with and obscure the underlying layer in proportion to the standard deviation value b) the introduction of viscoelasticity in the simulation shows that the intrinsic absorption attenuates the multiply scattered waves to reduce their influence on the results. Hence, a low Q upper crust may improve deep image quality.

T7-11

PRE-STACK MIGRATION OF WIDE-ANGLE CRUSTAL-SCALE SEISMIC RECORDS IN CROOKED-LINE GEOMETRY

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Deviations from a planar, two-dimensional (2-D) geometry are among the major limiting factors complicating pre-stack wide-angle migration. In the case of the ACCRETE wide-angle experiment, crooked-line geometry of the survey leads to 5 - 6 % distortion of the offsets amounting to unacceptable systematic errors in travel-times used in the migration. Relocation of source-receiver pairs commonly used to correct the offsets results in a smearing of the shallow structure and in a loss of ray-tracing accuracy. We present an alternative Kirchhoff migration scheme accurately accounting for the crooked-line geometry of the line. In our approach, with the use of an appropriate velocity model transformation, the sources and receivers remain at their original locations, and the correct offsets are used in forward ray tracing. An efficient and accurate paraxial ray tracing scheme is employed to generate 2-D travel-time maps which are stored and used in pre-stack migration of shot gathers. After an inverse transformation, migrated shot gathers are combined to into the final image. Application of this approach to ACCRETE wide-angle records using the Kirchhoff pre-stack migration program from Seismic UNIX shows a significant improvement over the results obtained using a conventional technique. The obtained deep crustal and Moho structure corroborates our recent model derived using travel-time tomography and forward ray tracing, and Moho topography correlates with the boundaries of imaged tectonic structures.

T7-12

PRE-STACK MIGRATION OF WIDE ANGLE REFLECTIONS BENEATH THE SOUTHERN ISLAND OF NEW ZEALAND

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We present wide-angle imaging results of the onshore-offshore and ocean bottom refraction data recorded along Transect 1 across the Southern Island of New Zealand during the 1996 SIGHT experiment. The 106 working instruments along this profile recorded over 4000 air gun shots fired from the R/V Maurice Ewing in the Indian Ocean, resulting in coherent intra-crustal, Moho, and shallow mantle reflections. The travel times of PmP arrivals picked from this data set are migrated in the seismic velocity model of Holbrook et al. (presented at this meeting) using pre-stack Kirchlhoff migration. The constructed image of the Moho near the Australian/Pacific plate boundary can be focused by modifying the lower crustal seismic velocities in the aforementioned seismic velocity model. After we have obtained a sharper image of the Moho in this region we apply the same migration approach to image the crustal and mantle reflectivity using the wide-angle seismic record sections.

T7-13

SINGLE-CHANNEL RECORDER TEST RESULTS FROM TWO ACTIVE SOURCE EXPERIMENTS

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The University of Texas at El Paso in cooperation with the Texas Universities Seismic Instrumentation Alliance and Refraction Technology, Inc. received a grant from the State of Texas to develop and procure 200 active source recorders (Model 125, Texan). The first 10 Texans have been deployed and tested on two active source experiments: 1) an explosion survey in the White Sands area, New Mexico, and 2) a vibroseis survey in Medicine Bow National Forest, Wyoming. Final specifications for the Texan and test results from the two surveys will be presented. UTEP have received additional grants from the Department of Defense and National Science Foundation for the purchase of at least 450 Texans.

THEME 8: Rifts, basins and extensional provinces

T8-01

DOBRE - LATE PALAEOZOIC RECONSTRUCTION OF THE STABLE CRATONIC MOHO OF EUROPE

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DOBRE (Ukrainian for "good") is a multidisciplinary study of the Donbas Foldbelt (DF) region of Ukraine that includes deep seismic refraction and reflection profiling. Planned to take place in 1999, it is expected to provide information fundamental to understanding processes controlling the syn- and anomalous post-rift evolution and inversion of the intracratonic Dniepr-Donets Rift Basin (DDB). The DDB is the most profound intracratonic rift structure in Europe, with over 20 km of Devonian and younger sedimentary infill, cutting across the East European Craton (EEC). The DF is the "inverted" and orogenically deformed south-easternmost part of the DDB that straddles the Ukraine-Russia border. DOBRE comprises a wide spectrum of ancillary geoscientific studies with a centrepiece of approximately 500 km of deep seismic reflection profiling and coincident seismic refraction/wide-angle reflection surveying, across the DF and along its strike to the adjoining Karpinsky Swell north of the Caucasus. The scientific motivation for DOBRE includes the study of processes of destabilisation of stable cratonic interiors; evolution (destruction/replacement or deformation) of the Moho and lower crustal/upper mantle processes during continental rifting; deep crustal processes affecting the post-rift evolution of rift sedimentary basins; thermo-mechanical and chemical-petrological properties of the lithosphere and interactions with the asthenosphere; the deep structure and evolution of the southern margin of the EEC and its juncture with accreted terranes to the south; and deep structural control on sedimentary basin formation and deformation on the EEC and its margin.

T8-02

GEOLOGICAL DEVELOPMENT OF THE NE GERMAN BASIN

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The NE German Basin (NGB) is an intracratonic basin containing in excess of 12 km of Phanerozoic strata. It is part of a series of related basins extending from the North Sea to Poland. Four broadly NW-SE-striking fault zones occur in the area. From north to south these are: the Tornquist Zone (TZ), the Caledonian Deformation Front (CDF), the Trans-European Fault (TEF), and the Elbe Line (EL). The region was significantly influenced by the Caledonian and Variscan orogenies. Crustal warping and block faulting in the Upper Carboniferous was followed by a major magmatic episode which extended up into the Lower Permian. This resulted in a thick volcanic succession of Permosilesian age. Initial basin subsidence, appears to have occurred without significant fracturing of the upper crust, since no normal faults with large vertical offsets have been observed. However, geochemical analysis of the volcanics indicates thermal destabilisation of the crust prior to initial subsidence. The newly-obtained seismic data (DEKORP/BASIN '96) from the NE German Basin provide the basis for a detailed examination of the geodynamic evolution of the region. This, together with a variety of borehole and industrial seismics, was used to correlate the broad structural and stratigraphic framework for the region. Further aims include the development of basin models derived from seismic and sequence stratigraphic analysis.

T8-03

THE NORTHERN RIM OF THE CENTRAL EUROPEAN BASIN SYSTEM - THE OFFSHORE-ONSHORE SURVEY *BASIN '96*

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The North German Basin is an intracontinental basin of hotly debated geodynamic evolution, extending from the Tornquist Zone -an inferred Paleozoic suture- to the Harz Mountains, and from the North Sea to Poland. The basin is a complex one with various geophysical anomalies, magmatic intrusions and several changes in tectonic and subsidence regime over the past 300 Ma. In 1996, DEKORP organized the project BASIN '96 to perform Basin Analyses and Seismic Investigations in North Germany. The seismic data were gathered as a combination of 800 km reflection line offshore (airgun array) with seismological stations recording simultaneously onshore, and 500 km reflection seismics onshore (vibroseis and explosive) to run a complete line through the entire basin and across its margins, and also across the Caledonian Deformation Front and the Tornquist Zone. Initial results reveal the offshore continuation of fault structures already mapped onshore, sedimentary inversion structures, the Moho depth, and deep crustal and upper mantle structures. These images lead in correlation with older seismic data to the location of the Caledonian Deformation Front in the investigated area, reaching far more south than previously thought. Terrane boundaries north of the Tornquist System and the decoupling of upper and lower crustal levels are discussed also.

T8-04

DETERMINATION OF THE SPATIAL POSITION OF THE MAIN TECTONIC ELEMENTS BY DEEP SEISMIC DATA IN THE CARPATIAN BASIN

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Two nearly perpendicular deep reflection profiles, with high-quality crustal and upper mantle seismic signatures, were recorded over the southern part of the Carpathian Basin. By an approximate determination of the main tectonic elements of the region, we established a spatial model of basin evolution, which relies on deep movements zones detected on deep seismic data. In a row of Neogen depressions slightly dipping shear zones have taken shape. Along those zones several kilometers displacements took place in both the synrift and postrift phases towards a domal uplift of the asthenosphere. A different system of steeply dipping shear zones was formed between the blocks moving in nearly opposite directions. This shear zone is detectable in two ways: a) by cutting through the nearly horizontal coherent reflections on profiles in dip and oblique directions b) by reflection of the shearing surface itself in oblique direction. The earlier recognized low-frequency high-amplitude reflections of known industrial seismic sections are located on the flanks of the steeply dipping crustal shear zone system.

T8-05

IMAGING ACTIVE FAULTS AND DEEP CRUSTAL REFLECTIVITY IN THE NORTH-AEGEAN TROUGH

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The North Aegean Trough, deepest among the Aegean marine troughs has been classically considered as a site example for discussing the evolutionary models of continental crustal structure towards thinning through extension. Earlier alternative interpretations lacked deep seismic information. The 1997 SEISGRECE survey of N/O Le Nadir used a "single-bubble" airgun array succeeding in whole crustal penetration. Conspicuous intracrustal reflectivity is detected already on the single channel normal incidence monitor and at wide-angle on land seismometers. Crossing multichannel profiles in the western part of the Thermaïkos basin which prolongates the NAT suggest a relation of the crustal fabric not only to its southern bounding North Anatolian strike-slip fault, but also to the direction of former Alpine convergence followed by post-orogenic exhumation of the neighbouring Olympus, Ossa and Pilion massifs on land. There is evidence for a geometrical, hence probably genetical link between an area of increased lower crust reflectivity and the roots to these massifs. A structural relation between major normal-faults revealed through recent sediments and this geometry of crustal reflectivity is also suggested and an approach to its geometry will be attempted by pre-stack migration.

T8-06

AEGEAN EXTENSIONAL CRUST: THE DIVERSE CASES OF THE CRETAN DEEP BASIN, CYCLADIC CORE COMPLEX AND CORINTH-EVIA ACTIVE RIFTS

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The Aegean domain has been submitted to extensional tectonics since at least middle Miocene, through several mechanisms which have combined diversely in time and space to result in the present crustal structure. Modes of extension have encompassed post-orogenic thinning of a crust thickened during the Alpine orogeny of the Hellenides, extrusion of Anatolia, back-arc spreading to the Hellenic oceanic subduction, narrow rift propagation in relation to the North Anatolian fault. Coincident marine multichannel normal incidence, and OBS and land-based wide-angle, reflection data could be obtained during the SEISGRECE cruise of N/O Le Nadir in 1997, which provide reflection images with whole crustal penetration, i) in the North Cretan sea, the deepest largest marine basin, located between the subduction at the Hellenic arc and the Aegean active volcanic arc, ii) in the Cyclades plateau of exhumed metamorphic core complexes, iii) in the active seismogenic rifts of Corinth and Evia. The images obtained in these contexts of recent or active extension can be discussed with respect to deep crustal reflectivity revealed originally in normal-incidence reflection surveys of the 1980's, in particular in Western Europe and related to past extension.

T8-07

CRUSTAL DECOUPLING AND DOMING DURING MIOCENE EXTENSION IN THE ALBORAN DOMAIN (BETICS, SE SPAIN)

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In the Alborán domain, brittle to brittle-ductile extensional detachments and low-angle normal faults attenuated the Alpujarride and Nevado-Filabride nappe-stacks during the middle Miocene. A major extensional detachment (Filabres detachment) having an overall displacement of the hangingwall towards the WSW, cut down-section the Nevado-Filabride stack. Along the detachment three different extended domains have been identified: an eastern proximal block, a central highly extended domain, and a western distal block. Extension in the upper crust is compensated by transverse N-S upward doming beneath the central domain (the Sierra Nevada core). Deep seismic imaging in the ESCI-Béticas 2 reflection profile cutting across the Sierra Nevada core shows a highly reflective deep crust overlying a sub-horizontal Moho (10.5-11 s twt), and a fairly transparent upper crust and mantle. The lack of Moho relief beneath a crust with differential values of supracrustal extension, suggests a mechanism of intracrustal isostatic compensation. A prominent mid-crustal reflector (5.5 to 6.5 s twt) is deemed to represent a decoupling level between upper and deep crust. Surface geology and seismic imaging suggest the occurrence of intracrustal flow and upward doming above this decoupling level as a response to supracrustal extension. Other observations, namely seismicity and vertical Vp inversions restricted to upper crustal levels and no volcanic activity in the core during the middle Miocene, are also compatible with mid-crustal flow.

T8-08

EARTH'S CRUST AND ITS ISOSTATIC CONDITION IN BAIKAL RIFT ZONE AND ADJACENT AREAS FROM DSS DATA

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Results of long-term investigations of the earth's crust in the Baikal rift zone and adjacent areas of Siberian platform and Trans-Baikal fold region by the DSS method have been reviewed. Maps of the Moho discontinuity depth and average crustal velocity are represented. Revealed peculiarities of these parameter variations indicate to the complex character of juncture of the platform and fold area crustal structures. It was found that the earth's crust can be divided at the level of 20 km into two structural stages within which the lateral variations of interval velocities are related by inverse correlation dependence. This is valid for both the platform and the fold region. Velocity features correlating with the Baikal rift zone position can be distinctly seen in the upper stage only. The density distribution in the earth's crust were computed on velocity-density correlation dependencies and were applied to evaluate an isostatic condition in assumption that Moho surface is the level of isostatic adjustment. It was revealed that crustal blocks in the fold region may be not isostatically balanced.

T8-9

THE BASIC CHARACTERISTICS OF THE STRUCTURE OF ANDA-FENGLE NEARLY VERTICAL SEISMIC REFLECTION PROFILE OF CHINA

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Near Anda-Fengle in the middle of Shongliao basin of China about eighty-one kilometre's nearly vertical seismic reflection profile has been acquired (simply named A-F profile), the direction of which is NNW-SSE. Its traversed geologic units are the middle faulted upwarping zones and the southeast faulted downwarping zones of shonglian basin and its traversed minor units are primarily Anda-Zhaozhou anticline belts, Xujiaweizi downwarping belts and Chaoyanggou anticline belts. The landform is flat and the elevation is about 13030 m. The primary outcome of data interpretation: The main reflectors are T1(Yaojia formation top interface),T2 (Quantou formation top interface), T3 (Denglouku formation top surface), T4 (Jurassic system top interface), T5 (the bottom interface of sedimentary basin). In the upper crust of A-F profile namely the upper basement of basin exist five groups of detachment fault belts from north to south named AD2, AD3, ZD4, ZD3, ZD2, among which the dips of ZD2 and ZD3 are northward and those of other three groups are southward. ZD3 is one strongly detachment zone consisting of a series of faults which gather at depth of 2.6 s in the south and converge at depth about 3.8 s with expansive length about twenty-six and half kilometres. On A-F profile Moho presents minimum depth of 10.2 s and maximum depth of 11.8 s, apparent main frequency of 18-25 Hz, intense amplitude, perfect continuity, thickness of 0.4-1 s and internal structure (parallelism, oblique intersection, lenticular body). Discussion: (1) The bidirectional detachment zones prove that the upper crust of A-F profile had undergone contrary stress field process. (2) The complicate structure of detachment fault zones (the configuration and constitution of fault surface) indicates the complexity of the interaction between structural stress field and upper crust media. (3) The configurations of detachment faults are probably not only one model of being steep above and flat below. (4) There is one case that the detachment faults with contrary directions intersected in the upper crust of Shongliao basin. (5) As a result of the different characteristics of stress and media detachment faults may be much longer or rather shorter. Sometimes we could not find its convergent location. (6) The detachment faults are often also the lower velocity zones.

T8-10

THE WICKIEUP BRIGHT SPOT, SW ARIZONA, AND CRUSTAL INTRUSION

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Deep seismic reflection data collected during 1986 by the Consortium for Continental Reflection Profiling (COCORP) across the Colorado Plateau/Basin and Range Transition Zone, exhibit a number of unusually strong reflections at upper and mid-crustal depths. A prominent suite of reflections in the upper crust (0 to 3 s) on Arizona line 5 (AZ5), the Bagdad reflection sequence (BRS), has been argued by some to be part of a Proterozoic sill complex. Beneath the Bagdad sequence, near the town of Wickieup, is a distinctive, subhorizontal event at 6 s, largely neglected in previous studies. Its amplitude (>12 dB above the background) resembles other "bright spots" (e.g. Socorro) which have been interpreted as magma. Moreover, like the Socorro bright spot, the Wickieup bright spot lies at the top of the lower crust (V = 6.6 km/s) as defined by seismic refraction profiles (PACE). However, comparison of amplitudes for the Wickieup bright spot with those of the Bagdad sequence (fortuitously recorded on the same seismic traces) indicates that the Wickieup bright spot has a reflection coefficient of only about 0.1, much less than what would be expected from a fluid filled crack. We suggest instead the Wickieup bright spot is a frozen sill, though possibly much younger than the Bagdad sequence. This analysis points to the need for careful quantiative analysis before inferring that unusual amplitudes require exotic lithology.

T8-11

SEISMIC STRUCTURE OF THE NORTHERN GULF OF CALIFORNIA (MEXICO)

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The seismic structure of the transtensional margin of the Gulf of California has been investigated by a densely sampled (80 m) refraction/wide angle reflection seismic information combined with gravity modeling. These data were acquired during the CORTES-P96 experiment, using the marine air source array of the 50 liters (3000 cu.in.) provided by the R/V Hespérides. This energy was recorded by 8 portable seismic instruments onshore and 5 OBS (Ocean Bottom Seismometers) offshore. We present the results from a 200 km-long NW-SE profile in the northern Gulf of California. This profile runs from San Felipe, Baja California, to Tepoca, Sonora, crossing the San Andreas-Gulf of California transform fault system. The seismic and gravity modeling constraints two thinned crustal areas, corresponding to the Delfín basin (an active rift/pull apart basin) and the Tiburón basin (a probably abandoned rift basin), which are connected by transform faults. On both sides of the profile, a progressive thickening of the continental crust is observed. Our results indicate a crustal thickness of 20 km at the basin margins and 16 km and 17 km below the Delfín and Tiburón basins respectively. Between both basins the crust thickens to about 19 km.

T8-12

A NEW PASSIVE MARGIN MODEL FOR THE NEOPROTEROZOIC AND EARLY PALAEOZOIC OF SE AUSTRALIA DERIVED FROM SEISMIC STUDIES OF TASMANIA

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The island of Tasmania in southeast Australia has a number of geological elements. The relationship between these elements is largely obscured by younger cover of the Tasmania Basin, including extensive dolerites which limit the ability of potential field techniques to map basement. Therefore the development of a robust tectonic model for Tasmania has been inhibited. A seismic program was undertaken to map the large scale structure of Tasmania at depth. Deep seismic profiles were collected offshore along the entire coastline; the airguns were also recorded at a number of seismographs deployed across the island, allowing low resolution 3D tomographic imaging. Short reflection profiles were also recorded onshore across structures which could not be imaged by the offshore profiling. The Proterozoic basement in the northwest and in the Tyennan Block in the core of the island is unreflective, except for mostly east dipping reflectors which project to the surface at block boundaries. In the east, however, the lower crust is broken into rotated blocks whose boundary faults are reflective, indicating progressively greater crustal extension of the Tyennan Block to the northeast, where a reflective lower crust is interpreted to be highly extended continental crust with passive margin sediments and possibly fragments of oceanic crust. The apparently complex geology of Tasmania therefore fits into a simple tectonic model in which several episodes of crustal extension occurred before oceanic crust formed to the northeast. The extended crust has now been inverted, probably from the northeast.

T8-13

TECTONICS OF AN EXTINCT RIDGE/TRANSFORM INTERSECTION, DRAKE PASSAGE (ANTARCTICA)

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The tectonics and geohysical characteristics of the Shackleton Fracture Zone (SFZ), a first-order NW-SE trending high-relief ridge across the Drake Passage, appear to be tipical of long-offset, strike-slip faults. This ridge intersects two extinct spreading centers, the Western Scotia Ridge and the Phoenix/Antarctic Ridge and it behaved as a transform fault when the ridges were active. We discuss swath bathymetry, multichannel seismic (MCS) profiles, magnetic anomalies and gravimetric profiles collected in a marine geophysical survey of the Drake Passage during the season 1997-98. The absence of a major sedimentary cover, due to the strong bottom currents and the combination of techniques, allowed a detailed description of the tectonics and nature of the oceanic crust near fracture zones, which provides a good insight of these significant features of the oceans. The boundary between the two major plates in the area, the Scotia and Antarctic plates, is a left-lateral transpressive fault zone located along the South Scotia Ridge and the SFZ, which extends northwestward across the Drake Passage between the Chile Trench and the South Shetland Block. The tectonic evolution of the central sector of the SFZ is complex, since it entailed several episodes of transform and transcurrent faulting, which began before 29 My with the openign of the Scotia Sea. Marine magnetic anomalies on both flanks of the extinct Antarctic/Phoenix ridge provide, moreover, a record of spreading, which extends back to about 23 My. Faulting along the SFZ has been mantained to present because the relative motion between the South American and Antarctic plates is transfered along the South Scotia Ridge and the SFZ.

T8-14

ANALYSIS OF DEPTH-MIGRATED SWAT SEISMIC PROFILES OFFSHORE SOUTHWEST UNITED KINGDOM

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New depth migrations of the BIRPS Southern Approaches Traverse (SWAT) profiles better constrain the geometry of the Western Approaches-English Channel and Celtic Sea basins and the deep reflectors imaged beneath them. This region has suffered a series of complex deformational events, each superimposing its effects on existing structures. Of particular interest is the role in basin development of a series of SW dipping reflections beneath the Celtic Sea basins, often attributed to the Variscan front on the basis of their upward projection to Variscan structures and variations in structural style, which occur toward the SW in the North Celtic Sea basin, suggest that the deep reflections may not have the pivotal role in simple shear deformation of the crust as previously suggested. Reanalysis of structural deformation in the basins suggest significant regional uplift and denudation in the Tertiary that reduced total crustal thickness. The lower crust is highly reflective across the whole region, suggesting that it has been significantly modified even after basin formation, possibly by basaltic underplating, which could have contributed to the regional uplift.

T8-15

THE TRANSITION FROM ONSHORE FAILED RIFTS TO OFFSHORE DIVERGENT MARGINS: CONSTRAINTS FROM DEEP SEISMIC REFLECTION PROFILES AND POTENTIAL FIELD DATA ANALYSIS

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This work dicusses the transition from onshore failed rifts to offshore sedimentary basins along divergent continental margins based on integration of deep seismic reflection profiling, potential fied methods, geological data, and tectonic analysis. The following themes are addressed: a) the geologic evolution of the onshore and offshore rift systems in the Brazilian northeastern margin; b) the potential field methods response to the deep crustal structures; c) the seismic expression of major structural features in the rifts and within the continental and oceanic crusts; d) a possible geodynamic model for the evolution of the rift system; and e) analogies with a number of failed rifts and passive margin systems in the North Atlantic. The sedimentary basins in northeastern Brazil comprehend a series of asymmetric grabens, including the onshore Recôncavo-Tucano-Jatobá rift system (RTJ) and the offshore Jacuípe - Sergipe/Alagoas basins (JSA). Pre-rift sediments include Paleozoic to Jurassic/Early Cretaceous sediments deposited above a basement that ranges from Archean rocks to Late Proterozoic metasediments. Major faults were formed in the Neocomian along the eastern border of the Recôncavo and Tucano basins, concomitant with deposition of fluvial and lacustrine sediments in the Sergipe / Alagoas Basin. The rift phase terminated in the onshore rifts with fluvial deposits above a major regional unconformity. No further expressive sedimentation is observed in the Recôncavo and Tucano basins, in a marked contrast to the geodynamic evolution of the Sergipe Basin, which is characterized by renewed phases of basement-involved faulting from Aptian to Early Albian,, followed by a thermal phase of subsidence. The overall picture of two branches of a rift system, with different geodynamic evolution following the inception of oceanic crust, has tectonic analogues in many other sedimentary basins worldwide. We suggest that the Tucano and Sergipe basins evolved as a result of regional lithospheric extension during the Neocomian, first distributed over a wide region, forming rifts along pre-existing zones of weakness in the crust, and subsequently, focussing along a deeper mantle weak zone, local of a posterior plate rupture. This mechanism has been proposed for the Newark Basin (onshore Eastern United States) and the offshore Baltimore Canyon Trough, based on a reasonable fit between geological observation and numerical modeling methods. Some major structures in the RTJ and JSA rift systems may also have analogs in the North Atlantic, particularly the Jeanne D 'Árc Basin in the Canadian passive continental margin, and the Eastern Greenland margin.

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