Frontiers in Earth Sciences

Series Editors: J.P. Brun, O. Oncken, H. Weissert, C. Dullo
Subduction is a major process that plays a first-order role in the dynamics of the Earth. The sinking of cold lithosphere into the mantle is thought by many authors to be the most important source of energy for plates driving forces. It also deeply modifies the thermal and chemical structure of the mantle, producing arc volcanism, and is responsible for the release of most of the seismic energy on Earth. There have been considerable achievements done during the past decades regarding the complex interactions between the various processes acting in subduction zones. This volume contains a collection of contributions that were presented in June 2007 in Montpellier (France) during a conference that gave a state of the art panorama and discussed the perspectives about “Subduction Zone Geodynamics”. The conference was held under the patronage of the “Société Géologique de France” in the frame of the International Year of Planet Earth sponsored by UNESCO and the International Union of Geological Sciences. During the conference, a volume of 172 abstracts has been published in the “Mémoires Géosciences Montpellier” vol. 41 (2007) and is available at Géosciences Montpellier Laboratory (http://www.gm.univ-montp2.fr). Twelve keynotes launched the discussion on the following topics: Geodynamics and Physical Models (S. Sobolev and T. Becker), Geodesy, Seismogenic Zone and Seismic Hazard (W. Thatcher and S. Das), Seismology (D. Zhao and P. Silver), Structure and Tectonics (R. von Huene and R. Wortel), Geochemistry and Metamorphism (Y. Tatsumi and S. Guillot), and Petrology and Mineral Physics (M. Schmidt and H. Green). We favored the multidisciplinary approach to debate on remaining key questions.

The chapters included in this special volume provide a sampling of the presentations given in Montpellier and offer a unique multidisciplinary picture of the recent research on subduction zones geodynamics. They were organized into five main topics: Subduction zone geodynamics, Seismic tomography and anisotropy, Great subduction zone earthquakes, Seismogenic zone characterization and Continental and ridge subduction processes. Each of the 13 chapters collected in the present volume is primarily concerned with one of these topics. However, it is important to highlight that chapters always treat more than one topic so that all are related lighting on different aspects of the complex and fascinating subduction zones geodynamics.
Subduction Zone Geodynamics

Seismological data as Wadati-Benioff zones and the distribution of tomographic anomalies illustrate short-term snapshot of the subduction process; the cold lithosphere sinks into the fluid-like mantle with different dips and shapes. However, the long-term evolution of subduction is still uncertain due to its transient character. Hence, to better understand the dynamics of subduction, seismic data need to be integrated with petrological, geochemical and structural constraints as well as numerical and laboratory models. Only modelling, in fact, can provide a dynamic view of the slab behaviour giving the opportunity to insert all the direct and indirect observables into a comprehensive picture. Recognizing the importance of modelling, Becker and Faccenna (this volume) offer a detailed and updated review on the subduction (numerical and laboratory) modelling and, in turn on current understanding of subduction dynamics, analyzing the process from a regional to a global view.

It is generally accepted that slab negative buoyancy provides the primary driving force for subduction. In this view, the subduction of areas of over-thickened oceanic crust (seamount chains, oceanic plateaus, island arcs), isostatically more buoyant than normal oceanic lithosphere, potentially affects the subduction behaviour influencing its kinematics, slab shape, seismic activity, arc volcanism and coastal geomorphic features. Royden and Husson (this volume) use three-dimensional semi-analytic “unforced” subduction models, in which trench kinematics is controlled only by slab buoyancy, with the aim of systematically analyzing the relationships between slab density, slab geometry and subduction velocity rates.

Subduction dynamics depends on the existence and the distribution of slab windows. Wortel et al. (this volume) address this question by focussing on STEP (subduction-transform-edge-propagator) faults that control the final stages of evolution of subduction zones. A STEP fault is a tear in the slab which decouples oceanic subducting lithosphere from continental buoyant lithosphere. This tectonic element allows the lateral lithospheric segmentation and, in turn, the continuation of an active subduction process once continental lithosphere is forced at depth. The central Mediterranean Sea is used as a case study because of its peculiar recent history.
240 scientists have attended the three-days meeting among which 180 Europeans and 60 from USA, Asia and other countries. (First row from the left: Francesca Funiciello, with her daughter (12th place) and Serge Lallemand (5th place))
Seismic Tomography and Anisotropy

The seismology is the most effective method to explore the structure of subduction zones at great depths. A major characteristic that makes the subduction zones different from other regions comes from the release of water from the sinking slab. This process leads to seismogenesis, melting and viscosity reduction and thus enhances the mantle flow. Mainprice and Ildefonse (this volume) explore the contribution of hydrous phases in seismic anisotropy by reporting the elastic properties and characteristics of the wave propagation in anisotropic media for a number of hydrated minerals.

Calò et al. (this volume) present seismic tomographic inversions of P- and S-wave velocity in the southern Tyrrhenian region based on the combined use of the Double-Difference technique for inversions, a recently developed algorithm for local earthquake tomography, and a statistical Weighted Average Model method. This innovative tomographic approach is capable to strongly improve the resolution of the final model giving the opportunity to highlight also heterogeneities within the Calabrian subducting lithosphere never visualized before.

Great Subduction Zone Earthquakes

Among the biggest challenges of this century, the earthquake prediction is highly ranked, especially those which focus on the great event occurring along some subduction zones. One can address the problem at different scales and using various approaches. In this section, the emphasis is first given at a macroscopic scale either from rupture characteristics or kinematics and structural considerations.

Based on several well-studied rupture processes during great earthquakes, Das and Watts (this volume) observe that subducting seamounts should play a significant role. The approach chose by Gutscher and Westbrook (this volume) is substantially different. They observe that many of the margins with broad accretionary wedges have produced strong earthquakes (M9) in the past, as well as giant tsunamis. They propose that these wide accretionary wedges promote larger co-seismic slips and rupture duration for shallow earthquakes because of their lower rigidity.

Seismogenic Zone Characterization

Before having the opportunity to drill, sample and monitor the seismogenic zone, we have no other choice than improving our imagery of the margin’s structure and mechanical behaviour using either detailed bathymetry, reflection and refraction seismics, seismology or geodesy. It is clear that marine and land observations have notably contributed in our understanding during the past decades.

Von Huene et al. (this volume) present a review of the current models based on high quality geophysical images of active margins. He refers to the Kelin Wang’s concept of dynamic Coulomb wedge model to explain the differences in strain during inter-seismic locking and co-seismic slip in a converging plate environment. The imaging of inter-seismic locking is a challenge for geodesists and only densely monitored regions can help us to elucidate, for example the occurrence of slow slip episodes.
and non-volcanic tremors along the brittle-plastic transition zones of the subduction interface. Such study is exemplified at the Nankai subduction zone and the results are presented in this volume by Aoki and Scholtz. They have used the vertical component of the GPS to discriminate the rigid plate motion from the deformation due to interplate locking.

**Continental and Ridge Subduction Processes**

Subduction processes partly differ from “classical” oceanic subduction when a continent or a spreading ridge subducts. The buoyancy, the compositional structure and the magmatic activity in the case of a spreading ridge obviously interfere with the “regular” subduction mechanisms.

At first, Guillot et al. (*this volume*) present a review of the exhumation processes in both oceanic and continental contexts based on petrological and geochronological data on HP-UHP/LT metamorphic rocks presently sliced in meta-sediments or embedded in “mélange” formations. Comprehensive two-dimensional thermo-mechanical models are proposed to account for the different settings of occurrence of these rocks. Then, a history of subduction episodes that produced the Taiwan orogen is developed by Chang et al. (*this volume*) based on constraints provided by the two “mélanges” recognized on the island.

Scalabrino et al. (*this volume*) review in their chapter the main events that occurred on land at the Chile Triple Junction where the Chile spreading ridge subducts beneath the Patagonian Cordillera. Tectonic, sedimentary and magmatic features are described chronologically and feed an evolutionary model of the area.

Finally, Mantilla-Pimiento et al. (*this volume*) present a detailed study based on two-dimensional seismic reflection data and potential field interpretations about the complex history of the active Colombian margin since late Cretaceous. They are able to image a huge oceanic basement complex sandwiched between an ancient continental tectonic wedge and the present active accretionary wedge.

Serge Lallemand
Francesca Funiciello
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