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SUBDUCTION
Insights from Physical Modeling

by

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TABLE OF CONTENTS

CHAPTER 5. JUMPS OF SUBDUCTION ZONES, SUBDUCTION REVERSAL, AND CLOSING OF BACK ARC BASINS

CHAPTER 6. CONTINENTAL SUBDUCTION

PREFACE

Of the two modeling methods, mathematical (numerical) and physical (experimental), I would prefer dealing with a computer, leaving the "dirty" experimental work to those who enjoy working with real physical objects. Mathematical modeling enables us to more easily vary parameters over a wide range and create such conditions and models which can never be implemented in the laboratory. However, this method encounters serious problems in constructing ever more complex and adequate models of geologic processes in spite of the great possibilities provided by modern supercomputers. Frequently, it is not even clear how to formulate the problem mathematically, for example, in cases where it involves large transient deformations and failure of the lithosphere at the plate boundaries, in particular at the convergent boundaries. In many cases, physical modeling can in principle obviate these difficulties which makes this method more attractive and deserving of further development. The main problem is to put the experiments on a quantitative basis, i.e. to create models that satisfy the necessary requirements, the similarity criteria, in the first place.

This work represents a coherent description of the physical (mechanical) modeling of subduction and subduction-related phenomena, including the similarity criteria, the experimental technique, results of the model experiments, theoretical analysis of the results on the basis of continuum mechanics, and their geodynamic interpretation.

The problem of physical similarity is considered in the first chapter. To create a physically similar laboratory model of subduction we apply a novel technique developed on the basis of using hydrocarbon model materials for modeling the lithosphere with properties strongly dependent on temperature. This technique and experimental facilities are described in the second chapter. Experiments are performed with elastico-plastic lithospheric models underlain by a low-viscosity asthenosphere. We use both 2-D and 3-D approaches. Driving forces of subduction are both lateral compression of the lithosphere by the piston and gravitational sinking of the subducting plate. Different modes of initiation and development of subduction under horizontal compression are studied in the third chapter. Subduction is modeled in general as well as applied to particular regions such as the Central Basin of the Indian Ocean where a new subduction zone is proposed to be initiating.

Chapter 4 concentrates on the back arc dynamics and its relation to subduction regime. The effect of hydrostatic suction between plates in the subduction zone is shown to be responsible for the back arc tension. The effect is due to the low effective strength of the lithosphere compared with the hydrostatic stresses within it. The back arc stress regime correlates with a departure from isostatic equilibrium in the arc-trench area and, hence, can be recognized in the free air gravity anomaly field. Situations in some particular regions with active back arc basins are considered as well. The Aegean region where back arc tension can not be explained using traditional models is one of them.

Chapter 5 deals with situations where the lithosphere in a subduction zone is subjected to a high compression caused by subduction of very young lithosphere, different asperities and especially of the continental margin. Under strong compression the lithosphere can fail in a new place resulting in a jump of the subduction zone to that place. Location of the jump, style of the lithospheric deformation preceding jump, as well as polarity of a new subduction zone depend on particular conditions. For example, subduction of the Asian margin under the Luzon arc seems to result in initiation of new subduction under northeastern Taiwan.

Chapter 6 presents results of the modeling of continent-continent collision with three-layer lithospheric model which includes a very weak lower crust. The crust undergoes complex deformation in the collision zone, being scraped from the underlying mantle layer while this layer itself subducts similar to the subduction of the oceanic lithosphere in "classical" subduction zones. Such a similarity justifies the title of the chapter *Continental subduction* and its inclusion in this book.

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