Preface

I consider *plate tectonics* as the Earth Sciences discipline that describes the geodynamic evolution of the lithosphere, coupled with the underlying "fluid" mantle, over long time intervals, of the order of million years. Such a description, which includes plate kinematics, mantle dynamics, and the geology of plate boundaries, is based on a variety of data from marine geophysics, paleomagnetism, seismology, structural geology, stratigraphy, paleontology, and geochemistry. Therefore, although traditionally plate tectonics has been considered either as synonymous with plate kinematics (by most geophysicists) or a discipline describing the structural geology of plate boundaries (by many geologists), I will try to present an integrated approach to this science, introducing concepts from most of the research fields listed above. In fact, despite that the modern society drives young scientists toward exasperated specialization, it is my firm opinion that a true expertise in plate tectonics should be based on a *holistic* view of the geological processes.

This textbook evolved from a series of courses that I taught over the last years at the University of Camerino, Italy, to students enrolled in the MSc programme in Geoenvironmental Resources and Risks. These students had a background in geology, geography, engineering, or physics, a level ranging from advanced undergraduate to graduate, and came from four continents. For many geology, geophysics, and environmental engineering students, knowledge of plate tectonics is generally *qualitative* and limits to a few consolidated principles and to some rudiments about plate boundary processes. This book was born from the idea that a number of students could be stimulated to undertake a more thorough study of plate tectonics after having acquired basic skills in introductory courses. For these people, attaining an in-depth knowledge of the physics of plate tectonic processes through a rigorous approach based on mathematical methods will be a pleasant adventure, not a boring exercise. In fact, any student that strives for understanding the nature of the forces that drive the large-scale geological processes is naturally led to consider mathematics as a fundamental method for describing the natural processes in their generality, not only as a tool for solving practical problems. This book can also be useful for researchers specialized in one of the several disciplines of geosciences, who have the necessity to learn techniques of plate tectonic modelling or simply desire to expand their knowledge. Unfortunately, with the exception of the classic volume published by Le Pichon et al. in 1973, there are no advanced books where a student can learn quantitative methods of plate tectonics and find a unified description of the laws that govern the motion of tectonic plates. This book attempts to fill the gap by first exploring the principles of plate kinematics in the first part (Chaps. 1, 2, 3, 4, 5, and 6), then trying to link plate motions to physical processes occurring in the lithosphere and the mantle in the second part (Chaps. 7, 8, 9, 10, 11, 12, 13, and 14). In order to be self-contained, the book includes three chapters (Chaps. 8, 9, and 10) that illustrate the basic principles of seismology, because this discipline represents a fundamental source of data for plate tectonics. Throughout the book, it is assumed that the reader has an adequate background in geology, geochemistry, and classic physics, while skills in computer programming are required for solving some exercises. With a few exceptions, reading this book does not require more mathematical background than the customary undergraduate courses in advanced calculus and vector analysis. As an aid to reading, two electronic appendices introduce vector analysis and algorithms are included at the end of this book. Finally, a basic understanding of plate tectonics at the level of the classic book of Cox and Hart (1986) is desirable. Some exercises have been designed to be solved with the help of professional software, either freeware or commercial. These software tools include two free computer programs that I designed for the analysis of marine magnetic anomalies and for making plate tectonic reconstructions, respectively *Magan* and *PlaKin*. Readers can freely download the software and the solutions to the exercises from http://extras.springer.com either to learn some techniques or for their own research purposes.

The special emphasis I give to computer methods shows through some chapters of this book and is clearly a consequence of my heterogeneous scientific background. Although I studied theoretical physics, my passion for computer programming led me to start working as a software developer and consultant in Milan, Italy, soon after my graduation. However, even in those days I maturated a strong scientific interest in the application of advanced algorithms to geosciences, in particular to plate kinematics. During that period, I designed and developed *PCME* (Paleo–Continental Map Editor) (Schettino 1998), an interactive computer program for making plate reconstructions. This event led me to get in touch with C. R. Scotese, a scientist who pioneered the application of computer methods to plate kinematics. At that time he was at the University of Texas at Arlington, and I started collaborating with him to the construction of a new atlas of plate tectonic reconstructions for the Mesozoic and the Cenozoic in the context of the Paleomap Project, as well as to the implementation of a series of advanced software tools for plate tectonic modelling. Starting from the beginning of the new millennium, my research interests focused on paleomagnetism, marine geophysics, plate kinematics at global and regional scale, and on the dynamics of subduction. The general conclusion at which I arrived during my studies, which is now a guiding principle in my approach to the analysis of plate tectonic processes, can be summarized as follows. For time intervals of several million years, tectonic plates move at constant angular velocity about stationary axes of rotation in any geocentric reference frame fixed with respect to the Earth's spin axis. Therefore, conditions of dynamic equilibrium must normally exist between driving and resistive torques exerted on the lithosphere. Such a global equilibrium is broken when new plate boundaries form, or existing ones become extinct, so that a new system of tectonic plates is established. Then, the plates of this new system start moving about new, generally different, rotation axes and with different angular velocities. New plate boundaries always form by propagation of lithospheric discontinuities from a source region toward existing active boundaries, where they will give rise to additional triple junctions. Occasionally, plate motions proceed in non-equilibrium conditions, because active asthenospheric flows driven by horizontal pressure gradients in the mantle exert an excess basal drag on the overlying lithosphere, determining significant variations of angular velocity and accelerated motion. In this instance, high spreading and subduction rates accompany the plate motions. The ultimate cause of such episodes of non-equilibrium plate kinematics is the presence of upper mantle thermo-chemical heterogeneities, in particular mantle plumes and subducted slabs. Plate motions that proceed in conditions of perturbed equilibrium are associated with spectacular and sometimes unexplained geological phenomena, but these events are uncommon in the history of global plate motions and must be viewed as the exception rather than the rule. Therefore, the equilibrium between driving and resistive torques exerted on the lithosphere, and the resulting invariance of the angular velocity vectors of tectonic plates for long time intervals, should be considered as one of the most fundamental laws of plate tectonics.

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Camerino, Italy

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