

# Chapter 1

## PREAMBLE

### 1.1 What is the dissertation about?

The dissertation presented here addresses the processes that influence the subduction and subsequent exhumation of high pressure rocks. The methods by which these processes are investigated comprise large scale structural mapping in the Western Alpine Sesia Zone, a large sliver of subducted continental crust, as well as the connection of the structural data with detailed petrological investigations. Structural investigations concentrated on the development of a regional scale fabric map of the Sesia Zone by combining existing and newly collected structural data in order to visualize and quantify the regional significance of different deformation phases that affected the Sesia rocks during subduction and exhumation. Petrologic investigations mainly comprise thermodynamic forward calculations in order to interpret chemically zoned metamorphic minerals by comparing numerically modelled growth zonation patterns with those observed in natural rocks. Information derived from the thermodynamic forward models comprises (1) fluid content of the host rocks during the metamorphic evolution and its influence on the physico-chemical properties of the subducted rocks, (2) the effect of element fractionation due to fractional crystallisation on the effective bulk rock composition and the resulting small scale disequilibrium textures as well as (3) the interpretation of chemical zonation patterns in metamorphic minerals in terms of reaction kinetics and its influence on conventional thermodynamic equilibrium calculations.

### 1.2 Structure of the work

The structure of this work comprises mainly three different parts: (1) a general introduction into the scientific issues addressed in the dissertation, (2) four scientific manuscripts, all of which are intended to be published, that document the results and discussions of the investigations that have been conducted in this dissertation and (3) a final summary and discussion of the data presented in the manuscripts in order to show how the different topics of the work are related to each other and to the general questions that are presently discussed in the scientific community. Additionally, at the end of this work the reader will find a

reference list for the entire work, acknowledgements as well as a printed and electronic appendix that contains the collected data, algorithms and formulas, reprints of the so far published manuscripts as well as relevant computer programs and spreadsheets used in this work.

### **1.3 Scientific manuscripts**

The main part of this dissertation consists of four manuscripts that have been submitted for publication in international peer-reviewed journals. These are all multi-author manuscripts and the contribution of each author is outlined below.

Chapter 3 contains the manuscript: “*Insight into the physico-chemical properties of a subducted slab from garnet zonation patterns (Sesia Zone, Western Alps)*” by Matthias Konrad-Schmolke, Mark R. Handy, Jochen Babist and Patrick J. O’Brien. The manuscript is presently in review at the *Journal of Petrology*. This is an investigation on the influence of rocks’ volatile content on the physico-chemical properties of subducted continental crust. It is set as the first scientific manuscript of the thesis because it describes processes during the subduction stage of Alpine metamorphism in the Sesia rocks. The first author was responsible for the ideas, the scientific content and for collecting the petrological, rheological and thermodynamic data that form the essential part of this contribution. He wrote preliminary versions of the text that were later edited and improved by the second author. Additionally, Mark R. Handy was responsible for the geodynamic interpretation of the P-T paths and the tectonic interpretation of the observed structures. The third author mainly contributed some of the structural data that form the structural background of the petro-physical investigations presented in the manuscript. With his experience in petrologic investigations of high-pressure rocks and his interest in subduction and exhumation processes, Patrick J. O’Brien encouraged and convinced me to go further into the topic of thermodynamic modelling and its use for the interpretation of subduction and exhumation processes of continental crust. Of course, all of the authors contributed to the discussions that make up the content and the structure of this work.

Chapter 4 is the manuscript: “*Kinematics and mechanisms of exhuming subducted continental crust in the Sesia Zone, Western Alps*”. It contains structural data that were collected primarily by the first and second authors during three field seasons. Some data and samples were also made available from preliminary field studies

and mapping courses conducted by the third author. The fabric map of the Sesia Zone and adjacent units is presented (Fig. 3) and, together with thermo-barometric and kinematic data, this map is interpreted in terms of possible exhumation mechanisms. This Chapter is the second manuscript in the thesis, because it presents the structural and regional background needed to understand the metamorphic and structural evolution of the Sesia Zone during exhumation. The authors (Jochen Babist, Matthias Konrad-Schmolke, Mark R. Handy and Konrad Hammerschmidt), Are all affiliated with the Freie Universität Berlin, Department of Earth Sciences. Clearly, the manuscript was also conceived by the first author. The first author investigated the northeastern part of the Sesia Zone and adjacent units (Monte Rosa, Piemont), whereas the second author worked in the southwestern part of the Sesia Zone. The fabric map in Fig. 3 was finalized by the first author as part of his own PhD thesis (in preparation). However, the first and second authors contributed equally to the compilation and interpretation of the data underlying this map (also used in modified form in Chapter 3). As in chapter 3, the third author was responsible for the geodynamic interpretation of the mapped structures and the P-T paths, as well as for the improvement of argumentation, semantics and grammar. As some of the structural data were collected by the second author, parts of the geodynamic interpretation are based on his contributions to the discussion and are reflected in the text. The fourth author (Konrad Hammerschmidt) as well as the Diploma students Silke Sämman and Rita Häußler conducted the age determinations that constrained the geodynamic interpretation of the early structures and are presented in the Appendix. Bert C. Sperber contributed structural data from the middle part of the Chiusella Valley that were used to construct the structural cross section in Fig. 4.5a.

Chapter 5 is a manuscript entitled: “*Volatiles, mineral stabilities and their effect on the forces driving exhumation of subducted continental crust in the Sesia Zone (Western Alps)*” by Matthias Konrad-Schmolke, Mark R. Handy and Jochen Babist. It deals with the influence of fluids, phase transitions, tectonics and the retrograde P-T path on the exhumation mechanism and the rheological properties of high-pressure rocks. The manuscript is submitted to the *Journal of Geophysical Research-Solid Earth*. The first author is responsible for the scientific approach, the structure of the manuscript and preliminary versions of the main text that were

later edited and improved by the second author. Apart from many interesting and helpful suggestions regarding the manuscript, Mark R. Handy contributed to the kinematic and geodynamic interpretation of the structural investigations and of the retrograde P-T trajectory derived in this work. All thermodynamic and rheologic calculations as well as their interpretation were performed by the first author. The second and third author significantly contributed to the discussion of the topic and improved the scope of the manuscript.

The last scientific manuscript in Chapter 6, "*Thermodynamic modelling of diffusion controlled garnet growth*", demonstrates the influence of sluggish element transport in high-pressure metamorphic rocks on the chemical zonation patterns of garnet. It is published in *Contributions to Mineralogy and Petrology*. The authors are Matthias Konrad-Schmolke, Mark R. Handy, Jochen Babist and Patrick J. O'Brien. The first author developed the calculation routine by which diffusion-controlled garnet growth can be simulated with the aid of thermodynamic forward modelling. He performed all calculations and is responsible for the structure and content of the text. The second and fourth authors, both native speakers, carefully editing preliminary versions of the manuscript. All co-authors, but especially Patrick O'Brien significantly contributed to the discussion and interpretation of the thermodynamic calculations and their relation to natural samples. The fourth author also contributed a sample that was used in the manuscript.

#### **1.4 Organisation of the appendix**

Due to the large amount of data used in this work the appendix is twofold: in the printed work the reader can find tables with the sample locations, solid solution models, calculation routines and rheological parameters used in Chapters 3, 4, 5 and 6 as well as a brief paragraph about the historical terminology in the literature of the Sesia Zone. In contrast, all analytical and structural data as well as computer programs used in this study together with PDF files of all conference abstracts and publications as well as talks presented at international meetings are in electronic form. To ensure compatibility to many computer systems most of the data is stored in simple file formats, such as plain text and tab-separated tables. The appendix is thematically arranged, i.e. all analyses, formulas, programs etc. are grouped into one folder with data belonging to a certain chapter stored in

separate files and folders. The electronic appendix can be found on CD-ROM on the third cover page.