

Alain Meunier
Clays

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With 262 Figures

 Springer

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This book has been translated by Nathalie Fradin (Fradin Traduction sarl) from the original work "Argiles", first published in France in 2003 in the series "Geosciences" by Editions scientifiques GB in collaboration with the Société Géologique de France.

ISBN 3-540-21667-7 **Springer Berlin Heidelberg New York**

Library of Congress Control Number: 2004114235

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springeronline.com
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Printed in Germany

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Cover design: E. Kirchner, Heidelberg
Production: A. Oelschläger
Typesetting: Camera-ready by LE-TEX
Printing: Mercedes-Druck, Berlin
Binding: Stein + Lehmann, Berlin

Printed on acid-free paper 32/2132/AO 5 4 3 2 1 0

Preface

This book is about the most complete work on the subject of clay minerals thus far conceived. Its scope is one of basics to general principles to use in real geologic situations. In principle any student, advanced student or casual researcher, should be able to find an answer to almost any question posed. The breadth of knowledge presented is truly impressive.

This presentation is especially important at present when the study of the most abundant minerals found near the Earth's surface, clays, appears to find disfavour with students and Universities. In fact we have never before needed such an encyclopaedic work to strengthen the discipline. At present when Earth sciences are slowing in popularity, the need for a precise and general education in the study of clay minerals is greater than ever before. Curiously the study of the environment, those materials found in the sphere of biological activity, is more relevant than ever. The natural progress of human activity through the age of science and then industrial activity up to the present stage of the post-industrial era has been marked by an increasing use of the Earth's surface resources. The steady increase of the human population has called upon the natural resources of the surface in a non-linear manner. In the pre-industrial era agriculture and industry was concerned with the basic subsistence of populations. In good years there was enough to eat and in bad ones not enough. The means of obtaining this production did not draw upon the natural mineral riches of the surface to any great extent. Animals were the major non-human motor force, and iron was only a subsidiary part of the production mechanism. Even in cities most of the means of heating remained as the natural, renewable sources of wood. This of course has changed greatly in the last 150 years.

Today not only the soil of the planet is solicited to produce more than subsistence for a vastly increased population but the desires of these populations to move about has drawn on the buried resources to respond to the high energy needs of motor transportation and total comfort heating. Skiing on the top of a mountain in January is the epitome of the triumph of modern man over the elements where an enormous use of energy and natural resources is used to gratify a desire for exotic experiences. These needs of comfort, abundance and pleasure draw on the natural equilibrium of the Earth's surface.

Clay mineralogy is then the study of the basis of the natural riches found in most surface layers of the Earth. Application of the accumulated knowledge about these fundamental portions of our environment will allow us to search

more efficiently for petroleum resources, for metallic concentrations and for an increased efficiency of farming practices. These are the positive aspects of our present human experience. However, as is more and more evident, the negative side of current human activity creates high concentrations of toxic material in the surface environment, and perhaps in the near future at some undetermined depth (toxic, nuclear waste). These must be dealt with intelligently and oft times in great haste. Such problems involve, or should involve, knowledge of clay mineralogy. The natural chemical stability (in chemical – time space) of clays, their physical properties and chemical influences must be known in order to deal efficiently with modern day problems involving the environment. In this sense the book proposed by Alain Meunier is not only timely but also essential. No other work has attempted to unite the dispersed and rich knowledge of clay minerals into a single volume. One can find the relations of chemical stability, X-ray diffraction identification, natural occurrence and abundance, reaction rates and physical properties of the minerals and many other aspects are explained and documented in this text. Virtually all of the major questions concerning clay minerals are treated here.

Thus this book can be used as a resource for teaching clay mineralogy or for students or as a guide for research people from other fields who wish to explore the problems of clay mineralogy on their own. It is sufficiently clearly written so that one can use it as a beginner or an experienced professional working in a field that will need some expertise in clay minerals. This is especially important today when we find a change in the structure of science beginning to modify the classical frontiers of our ancient disciplines. As old boundaries change, new needs arise and a fundamental understanding of clay minerals will always be of greatest help in dealing with the surface of the Earth that is the future of mankind.

Bruce Velde

Foreword

Clays are not the most abundant components in the mineral kingdom when compared to olivines of the Earth's mantle or to feldspars of the continental crusts. However, they hold a special place in scientific research because their environment is criss-crossed constantly by human activity. Indeed, inasmuch as they characterise soils and altered rocks, clays are at the centre of farming activities and civil engineering works; they are formed in diagenetic series prospected for petroleum resources; they crystallise in geothermal fields whose energy and mineral deposits prove valuable. Clays play an important part in everyday life, from the white-coated paper on which we write to the confinement of hazardous waste storage, from cosmetics to pneumatics, from paints to building materials.

Clays alone form an entire world in which geologists, mineralogists, physicists, mechanical engineers, chemists find extraordinary subjects for research. These small, flat minerals actually interface widely with their surrounding environment. They absorb, retain, release, and incorporate into their lattice a great variety of ions or molecules. Their huge external surface area (as compared with their volume) makes them first-class materials for catalysis, retention of toxic substances or future supports for composites. Clays are made up of particles that form stable suspensions in water. These suspensions have long served in drilling applications or tunnel piercing techniques. Suspended clays flow as liquids, thereby both helping to shape manufactured products such as ceramics, but also causing tragic mud flows, lahars or landslides.

In view of the tremendously rich research in the field of clays, this book deals only with the geology, the mineralogy or the chemistry of these minerals. Industrial applications, natural hazards and civil engineering could each be the subject of a separate work, and consequently are not addressed here. This work is heir to two books that made a deep impression on me: "Géologie des argiles" by Georges Millot (1964) and "Clay Minerals. A physico-chemical explanation of their occurrence" by Bruce Velde (1985). I have been fascinated by their comprehensive vision of processes ranging from the scale of the mineral to that of the landscape. They present both a brilliant synthesis and a visionary interpretation of the knowledge of their time. More than ever, I feel like a Lilliputian perched on these Gullivers' shoulders!

When the field pedologist or geologist picks up a lump of earth or breaks a chunk of altered granite or clay sediment, he actually examines clay minerals

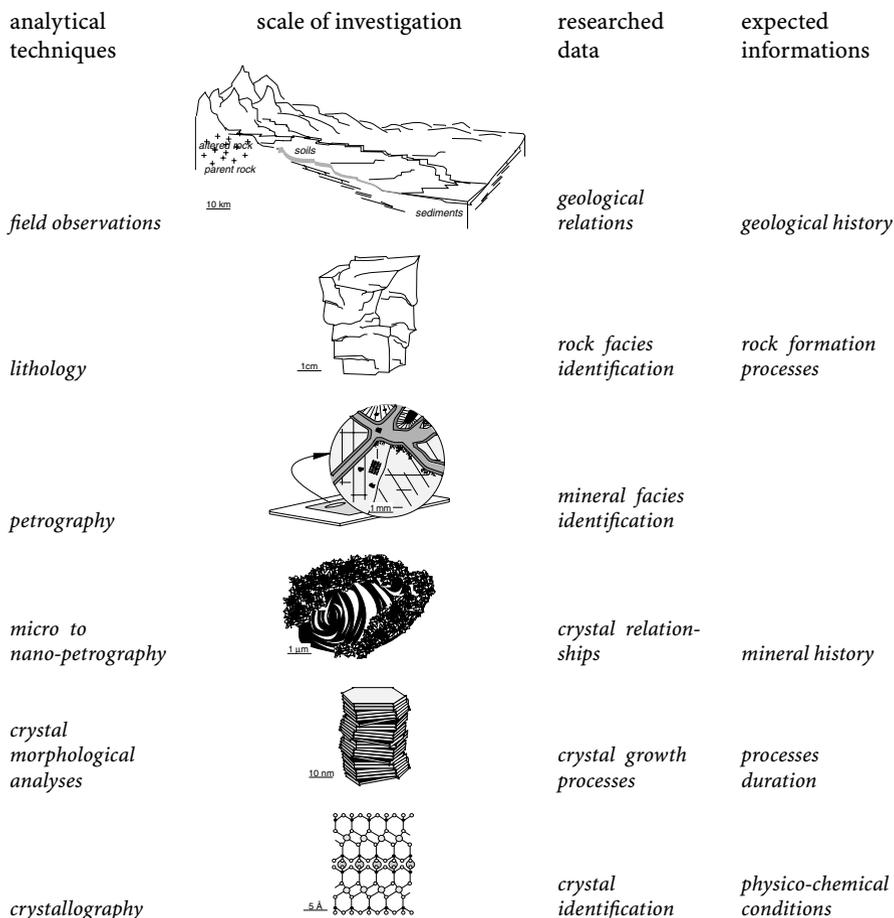


Fig. 1. Sketch showing the relationships between the different observation scales in a geological study of clay-bearing rocks.

that form complex textures on a scale of one millimetre. In order to understand how such textures have been formed, he must “dismantle the system”, meaning he must reach increasingly elementary components: aggregates, particles, crystals and eventually layers. The analysis of each organisational level helps to understand the mechanisms responsible for the genesis of clay minerals and reveals secrets of the rock’s formation (Fig. 1).

This book is directed to beginners in clay science. It is aimed at providing clues to “extract the message” underneath the crystallographical characteristics of clay minerals, as well as through their textures in rocks or soils. The book is divided into two parts:

- *Fundamentals (Chap. 1 to 5):* To deal with the basic concepts of thermodynamics specific to clays, it is first necessary to know the crystal structures

and the rules defining the chemical and isotopic compositions of these phyllosilicates. Surface properties are presented to introduce cation and anion exchange phenomena, as well as their ability for flocculation, aggregation or, on the contrary, dispersion. This is an introduction to the study of the mechanical and rheological properties that characterise the microstructure of natural or artificial clay materials. When necessary, some specific points are developed in separate boxes in the text.

- *Geology of clays (Chaps. 6 to 10)*: The initial acquisition of the fundamentals helps to understand how mineral reactions are determined in the world of clays. Their remarkably high reactivity allows the effect of the passage of time to be measured. This dynamic aspect underlies the presentation of soils and alterites, sediments, diagenetic and hydrothermal formations.

This book ends with a fascinating aspect of these minerals – despite their reputation for fragility, they subsist and form under extreme conditions. In this respect, an astonishing parallel can be drawn between clay and life: both often prove to be much more tenacious than expected.

The main purpose of this book is to share, beyond the facts, my enthusiasm for the study of minerals, undiminished after so many years. This enthusiasm has been kept alive by all the students (more than forty to date) who have done me the honour of working with me. They will be in my heart forever.

The information presented in this book derives in small part from my personal work, from my reading, and for the greater part from countless and sometimes animated discussions I have had with my colleagues from Poitiers (Daniel Beaufort in particular), but also with Bruce Velde, Alain Baronnet, Bruno Lanson and many others. I will never thank them enough for their contribution and am forever indebted to them. I also wish to especially thank Philippe Vieillard who had the courage to review the chapter dedicated to thermodynamics. I am highly indebted with Andreas Bauer who had imprudently promised me to read the English version of the book. He did it courageously!

The references used, although numerous, are notoriously incomplete, as is my knowledge. I hope that those whose work could not be quoted will not hold it against me: they are cited in the articles I reference. Searching the literature is a treasure hunt for which a solid point of departure is absolutely essential. I hope I succeeded in elucidating a starting point for more than a few domains.

Alain Meunier
Poitiers – December 2001

I wish to thank Alain Meunier for his faith in my work. This book has been a deeply enriching experience on both a professional and personal level.

Nathalie Fradin
Neuil – July 2003

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