

ENERGETICS OF GEOLOGICAL PROCESSES

EDITORS

**Surendra K. Saxena
and Somdev Bhattacharji**

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Hans Ramberg on his 60th birthday

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FOREWORD

Hans Ramberg is working in an area of geology where 60 years are a short, often negligible period of time. This is not so in the lives of men. For us it is a time for evaluating past accomplishments and a time for friends to express their appreciation and admiration.

Some universities have become famous for this ability to foster eminent scientists in one or several fields. The success of Cambridge University in physics is a well-known example, but if we ask ourselves whether the success of Oslo University in earth sciences is not equally astonishing, then we see that Hans is yet another example of this process; but it is not the whole story.

There were certainly promising prospects when he started his studies in geology: V. M. Goldschmidt had just come back from Göttingen in Germany and Tom Barth had returned from the Geophysical Laboratory in Washington, D.C. Two leaders in geochemistry and petrology at the same time! Hans became a student of Barth, specializing in metamorphic rocks and their problems; but soon the situation changed. Norway was occupied by the Germans and the possibilities for university studies almost vanished. However, in spite of all difficulties he obtained his Ph.D. in 1946 and began participating in the geological mapping of Greenland. In 1947 he went to the University of Chicago and stayed there until 1961 when he came to his present position in the University of Uppsala, Sweden.

From this synopsis of his career it is clear that he has spent practically his whole working life out of Norway. Scientifically, Hans has also lived far away from the mainstream of Norwegian geological research; but his heart is in Norway, in the Trondheim area with its Caledonian mountains. This is the place to which he returns: where he was born, where he started his research and where he still derives inspiration for new developments.

His scientific work has centered around the application of basic physics (in his case thermodynamics and mechanics) to the problems of petrology and tectonics. It is as easy to define these interests as it is difficult to put them into practice. Natural systems are so complex that our models of them easily become unrealistically simplistic. Hans started along the thermodynamic line and his contributions were of major importance to the development of petrogenesis. Even so the great success came when Hans started his famous experiments in centrifuges; in this field his contributions are fundamental.

My first knowledge of Hans came during the War through Norwegian student refugees in Stockholm; he was described as a most promising student. Then his first papers arrived and I was impressed by his fresh approach to the classic problems of metamorphism and metasomatism. I first met him in Oslo in 1946 during a lecture tour. We had little time for discussions so my most vivid recollection is that he was good at coasting when we ran down from Holmenkol-

len to Oslo! When we spent half a year together in Chicago in 1947–48 I began to appreciate his great gifts fully. Since then this impression has only been strengthened.

Hans should not be surprised that we have found out his age since after all, we have succeeded in determining the age of such a reluctant lady as Mother Earth. The result is this book, with which a score of his friends congratulate him on his sixtieth birthday!

May, 1977

University of Stockholm, Sweden

Frans E. Wickman

FOREWORD

Students who are provided a surfeit of definitive answers and final solutions are taught that it is not necessary to question; the answers are there and will be provided; all the students need do is acquiesce in the assimilation of them. These students may also be taught to regard a knowledge vacuum—of whatever extent—as intolerable, and to feel more anxious to have their knowledge-space filled with something than to review critically whether that something fills the space appropriately. An authoritarian assertion, said to be appropriate and correct, is to be accepted without attempting any assessment of its appropriateness and correctness by application of one's own critical capacities, and may even be welcomed as absolving one of any responsibility should the assertion prove to be wrong. By acquiescing to authority the hope is that the responsibility for being wrong will rest elsewhere. What one dutifully does is to perpetuate what one has been told is right and to contribute by filling interstices with bits of information—a safe way to live, or so it seems. What this approach ignores is that the responsibility for error is not avoided, but is assumed and remains fully shared; one is never absolved of the responsibility to apply one's own critical capacities to the assessment of the appropriateness and correctness of the fabric and structure and of the guiding principles and concepts of one's science.

Consequently, one of the important qualities of a teacher of geology—or of any science—is to stimulate and facilitate questioning and testing by the minds of students. Answers may be suggested, but only in order to be tested; dogma is rejected as such, but its assertions are taken up for examination and dispute. Imaginative hypotheses are prized, even if they turn out to be wrong, because they require scrutiny of possible relationships between apparently disparate facts and principles. Dispute is good because it forces examination; a “wild idea” may be defended tenaciously until it has been demonstrated to be untenable, and then it is happily abandoned. For those who genuinely warrant the designation *student*, regardless of age or experience, honor is not bound up with the positions which are supported during evaluation; rather, to the extent personal honor is involved it is in the clear devotion to the advancement of insight and knowledge. Honor becomes attached to process, not to specific outcomes, to intellectual approach and aspirations, not to personal theories.

In thinking about Professor Hans Ramberg's role in the geological sciences, I am reminded of an occasion during the summer of 1955 when he and I went fishing in Åsenfjord, an inner arm of Trondheimsfjord. His role on that fishing trip in relationship to me was analogous to his role as a geological scientist in relationship to his students, the geological community, and his science.

As we started that trip, both having good eyesight, we had the opportunity to see the same things. However, I, a Chicago-raised nonfisherman, discerned no

meaning in certain observations—Hans did. So he guided us to a place in the fjord, he provided me with the necessary equipment, told me how it could be used, and steered our boat, and I proceeded to haul in saithe as fast as I could get a multiple-hooked device into the water, back into the boat, and get the fish off the hooks. That fish story is, of course, one I shall never forget; it was tremendously exciting and it was enjoyable and rewarding to be so successful, but I would not have had anything like the catch I did—several score fish (really!)—had I been alone about it.

What analogy do I see? If not perfect—as perhaps no analogy is—I would note that in the initial observation he demonstrated the ability to discern what would likely be a promising area (he formulated the problem in such a way that success was greatly increased); he then gave me the appropriate fishing equipment (he provided what would be necessary to address the problem—intellectual tools, analytical technique, theoretical framework), told me what to do with the equipment (gave instruction, interpretation, and guidance so that the problem could be effectively addressed by me); and he steered the boat (kept us to the problem area that would be most fruitful). That is, his role has been to question and help others to question, to develop what was needed to address the questions and provide assistance in using his additions to our intellectual arsenal, and continually keep us focused on what would be productive. What Hans did *not* do on our fishing trip—which would also have been little fun for me—was fish all the fish and dump them in my lap! He did not do the job for me and then hand me the result. My little analogy breaks down badly in at least one respect; on that fishing expedition I caught most of the fish.

Hans Ramberg, explicitly and by example, is a teacher of the probing inquisitive study of science rather than of the authoritarian direction of information gathering. Whether one experiences him in the classroom, where his humor and devastating critiques of authoritarian positions are allowed to unfold, or in the colloquium discussion, where he gently explores weaknesses of hypotheses and stimulates to further inquiry, or in his formal publications which seriously and systematically set forth the results of research and thought as they exist at that stage of the continuing evaluation of knowledge, one is compelled to respect his devotion to the improvement of our science by thrusting ahead into the unexplored and by constantly ridding us of the “baggage” that no longer contributes to the improvements of our understanding that we seek.

Hans Ramberg has been an innovative leader in the exploration of new directions and the assessment of new approaches in the study of earth crustal phenomena. His career has been especially characterized by (1) the application of the principles and theory of physical chemistry and thermodynamics to the theoretical evaluation of hypotheses concerning the evolution and genesis of plutonic rocks; (2) the development of experimental determinations of fundamental thermodynamic properties of geologically important materials so as to constrain the evaluation of hypotheses; (3) the careful observation of rocks in the field so as to determine the geological factors that must constrain genetic theory; (4) the development of experimental methodology for the simulation of small- and large-scale structural phenomena of the crust, especially emphasizing scale model tests of the mechanical properties of segments of the crust and the influences of variations of those properties; and (5) the application of mathematical models to the understanding of the mechanical behavior of the crust.

Looking at a recent list of Professor Ramberg's publications, it is clear that the first half, up to 1961, demonstrates a clear emphasis on the application of

chemistry to the solution of geological problems, while the second half demonstrates a shift of emphasis, that began in 1955 and became dominant in 1961, toward the application of physics to the solution of geological problems.

It is noteworthy that all through his career, while occupied with theoretical and modeling studies, Professor Ramberg has continued field work. His philosophy has always been that theoretical considerations must be tied to observed geological field relations, structures, and mineral assemblages. The interplay between field geology and the laboratory/theoretical geology conducted indoors generates new ideas and revises or rejects old ones that prove to be invalid. Such a synthesis is able to be most fruitful when performed by a single individual making both approaches. Over the years he has generated many ideas. His book, *The Origin of Metamorphic and Metasomatic Rocks*, and many of his papers both before and after, treated many problems in mineral chemistry related to the structures and assemblages of metamorphic rocks and what the petrogenetic significance of these are. Throughout his work he attempted to emphasize quantitative approaches and point the way to solutions that could be found by experimental and modeling studies. Professor Ramberg has been an outstanding source of ideas for researchers in thermodynamic mineral chemistry and petrology over three decades.

Since the early 1960s Professor Ramberg's work in the mechanics of geological processes has won wide respect and represents a new approach to geological problems. It is valued as being correct in terms of its mathematics and physics. He has used this work to question "fad-ism" with regard to plate tectonics, but I know from personal conversation with him that his motivation is to cause us to pause and think about problems and questions, not to deny the real power of the plate tectonics concept. This work in geodynamics is his most unique research. In his geochemical work he has achieved a position among the leaders, but his geodynamical research has achieved for him a position of splendid isolation. He has synthesized research based upon experimental models, mathematical models and analysis, and detailed and regional field studies in forging ahead to reach new levels of understanding of small-scale and large-scale geological structures. His work has been prized by those engaged in extraterrestrial studies as well as engineers investigating the responses of materials at the earth's surface, and not least by his intended primary audience, the geologists engaged in the study of the deformation of the earth's crust.

Hans Ramberg is a buoyant person, lightness rather than great seriousness being the essence of his nature. These words are used in the definition of *levity*, his personality being in striking contrast to his constant concern for *gravity* as a phenomenon to which attention must be drawn in the interpretation of geological features. Since his very earliest published works, and in the context of both geochemical and geodynamical problems, the effect of gravity has been continually noted and has, of course, been central to his innovative model experiments using a large centrifuge. It may be that it will be through his contributions to our understanding of gravity-driven processes that Hans Ramberg will be longest remembered.

Professor Ramberg's contributions have not been limited to what is represented by the record of his publication list. He has characteristically scrupulously refrained from adding his name to the publications of research students and post-doctoral fellows who have worked under his guidance while a professor at the University of Chicago (1948–1961), a professor at the University of Uppsala, Sweden (1962–present), and a part-time professor at the University of

Connecticut (1970–present), unless he had personally made a major contribution to the day-to-day work of the research and to the written report. He has not claimed co-authorship where his role has been in conception, inspiration, definition, encouragement, and critical appraisal; but his contributions through his students have also been large and have continuously emphasized the application of rigorous theoretical and experimental chemistry and physics to the solution of geological problems.

Professor Ramberg has consistently risked unpopularity by questioning dominant paradigms rather than “falling into line” to get the most quick mileage possible out of what was most in vogue at the moment. His independence of thought and his devil’s advocate roles have helped to keep physical and chemical inquiry focused on soft spots in geological hypotheses and theories as they have been developing. This is a contribution of great value for which the geological community owes Professor Ramberg recognition and gratitude. At times, positions that he has inquired into, and perhaps therefore been identified with, and advocated in order to achieve the test of controversial assessment have finally proven to be wrong. Even so, the test of one position against others has proved to be an important service. But more, he has been a leader in invoking new approaches to inquire into unsolved problem areas. His work has stimulated both those closely associated with him and those who have become aware of his work, to seek deeply and more widely; he has catalyzed geochemical and geophysical research for 30 years, half of the time working in the United States and half of the time in Europe. I am proud to have had some professional exposure as well as personal association with one of the major post-World War II contributors to the movement in geological science to apply chemistry and physics to the solution of geological problems.

May, 1977

State University of New York at Buffalo

Paul H. Reitan

PREFACE

This volume is dedicated to Hans Ramberg on the occasion of his 60th birthday by a number of admirers, friends, colleagues, and former students as a token of their high esteem and affection. The title and division of this volume into two broad categories, geodynamics and geochemistry, illustrate the important fields in which his influence as a pioneering researcher and teacher has had its greatest scientific impact.

It was not an easy task for the editors to select a limited number of authors for this volume from the large world-wide circle of admirers, friends, and former students of Professor Ramberg. The editors are painfully aware that many of Professor Ramberg's former students and admirers who have gained eminence and reputation as geoscientists could not be invited to contribute to this volume because of the limitation on the number of pages.

In this volume we have compiled original researches, reviews, and ideas of the contributors in the fields of geodynamics, structural geology, geochemistry, and petrology, a cross-section of the areas in which Professor Ramberg's own original contributions have been prolific. Because of the diverse topics of the papers for this volume, it was not possible to arrange them in any logical order beyond the broad subdivisions geodynamics and geochemistry. However, readers may notice that the topics of wider scope appear earlier in the book.

Throughout the preparation of this volume, we have received valuable secretarial and clerical support from the Department of Geology of the Brooklyn College of the City University of New York. We are deeply grateful to Mona Saxena and Lee Bhattacharji, for their support, encouragement, and patience. The efficient and skillful editorial help of Ruth Adams and her deep interest in this volume greatly expedited its publication. Finally, we would like to thank the contributors for their promptness in sending the papers and in dealing with editorial requests.

May 1977
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I

**ENERGETICS OF
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