Handbook of Exploration Geochemistry

G.J.S. GOVETT
(Editor)

VOLUME 5

Regolith Exploration Geochemistry in Arctic and Temperate Terrains

L.K. KAURANNE, R. SALMINEN
and K. ERIKSSON

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HANDBOOK OF EXPLORATION GEOCHEMISTRY

G.J.S GOVETT (Editor)

1. ANALYTICAL METHODS IN GEOCHEMICAL PROSPECTING
2. STATISTICS AND DATA ANALYSIS IN GEOCHEMICAL PROSPECTING
3. ROCK GEOCHEMISTRY IN MINERAL EXPLORATION
4. REGOLITH EXPLORATION GEOCHEMISTRY IN TROPICAL AND SUB-TROPICAL TERRAINS
5. REGOLITH EXPLORATION GEOCHEMISTRY IN ARCTIC AND TEMPERATE TERRAINS

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Regolith Exploration Geochemistry in Arctic and Temperate Terrains

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with

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EDITOR'S FOREWORD

Regolith Exploration Geochemistry in Arctic and Temperate Terrains is the fifth volume in the Handbook of Exploration series which, together with the volume *Regolith Exploration Geochemistry in Tropical and Sub-tropical Terrains* covers the use of overburden in exploration geochemistry. This book, as with other volumes in the series, is designed to be of practical assistance to the field geologist as well as providing a comprehensive review of the subject that will be a reference source for research workers.

It is axiomatic that those best qualified to produce a work such as this book are also too busy to undertake it. It was, therefore, with considerable trepidation that I asked Professor L.K. Kauranne to be senior editor of the book. I was aware that Professor Kauranne was Director of what I believe to be the largest Geological Survey in northern Europe; I was also aware that he had founded and nurtured one of the world's foremost exploration geochemistry departments at the Geological Survey of Finland. It was the latter experience I wished to capture for the Handbook series.

Whereas I was successful, Professor Kauranne was rather less lucky in obtaining support from other busy people, e.g. in North America. My original concept of this volume was that it would deal with till and soil geochemistry in the glaciated and temperate zones of the northern hemisphere, but because of the lack of input from North American geochemists, this book is confined to Europe — and dominantly Fennoscandia.

During the time I worked as a geochemist in glaciated terrain I largely avoided the problems of till by concentrating on rock geochemistry. This book is an elegant example of the old adage that necessity is the mother of invention — the blanket of till that smothers the land surface is regarded by the Fennoscandinavians as a rare gift in providing a homogenized average sample of the underlying bedrock.

As in all exploration geochemistry, the exquisitely simple principles prove agonizingly difficult to implement in practice. The key to successful applications of exploration geochemistry to surficial materials in glaciated terrain is to thoroughly understand the processes that gave rise to the overburden. For this reason, the first five chapters of this volume are largely devoted to Quaternary geology. The importance of these chapters cannot be over-emphasized; the history of exploration geochemistry is littered with examples of "failures" that, with hindsight, are clearly attributable to an inadequate understanding of surface processes.

In this, as in the other volumes in the Handbook series, adequate space has been given to allow ideas and procedures to be explained in sufficient depth to permit the practising exploration geologist to understand — and apply — the principles. The practical aspects are emphasized by the inclusion of chapters on field methods, case histories, analytical techniques, and data interpretation.

This volume specifically addresses the use of till in exploration geochemistry, but many of the principles and techniques can be applied to other sample media. The imaginative data display techniques should prove to be especially useful to exploration geochemists and geologists in all geological and geochemical environments.

G.J.S. GOVETT
Helsinki, Finland and Sydney, Australia

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We are indebted to Professor Gerry J.S. Govett who in asking us to write this part of the *Handbook of Exploration Geochemistry* not only expressed his trust in us but also supported us with his own enormous enthusiasm. The secretaries Sirkka-Liisa Ollikainen and Asta Sainio retyped all the problem manuscripts, some of them several times; geologists Sinikka Roos and especially Erna Kuusisto painstakingly compiled the texts, compiled the indexes and assisted in innumerable other ways. Heli Moberg with the assistance of Soili Ahava and Pirkko Kurki drafted the hundreds of figures. We would like to express our sincere gratitude to all of them. Kathleen Ahonen deserves a special word of thanks for battling with our often mysterious use of English, improving both the fluency and logical flow of the texts. If in the end something remains amiss in either the texts or illustrations, please do not blame the wonderful ladies; the fault lies entirely with the writers.

KALEVI KAURANNE

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Chapter 1

INTRODUCTION

SCOPE AND CONTENTS OF THIS VOLUME

The purpose of this volume of the *Handbook of Exploration Geochemistry* is to assist the geologist in the use of overburden materials in geochemical exploration. The properties of the materials to be assessed, sampling, analysis and the interpretation and presentation of results are all described. Geographically the present volume is limited to arctic and temperate regions. A companion volume covering the soil geochemistry of tropical and subtropical regions will be appearing about the same time.

Together these volumes describe the geochemical analysis of the Earth's unconsolidated overburden, both the *in situ* residuum of weathering and the transported mineral drift. Other volumes of the Handbook are devoted to the use of rocks, stream and lake sediments, organic materials, water and air in prospecting (Fig. 1-1). As chemical analysis and data interpretation are also treated in separate volumes of this series, they are touched upon here only briefly.

Chapters 2, 3 and 4 describe the characteristic materials of the overburden in arctic and temperate regions, their origin, structure and geochemical character. A general description of the weathered bedrock, glacial till, glacifluvial formations and more recent alluvial sediments and organic deposits is presented, together with the types and properties of soil. Regional and local scale geochemical dispersion of elements, and the details of different transport mechanisms, are discussed in Chapters 5 and 6; understanding of the dispersion is the key to the interpretation of results.

Chapters 7 and 8 provide a short introduction to field work — to the different sampling, analytical and data processing methods appropriate for the different scales of study and to the equipment and measurements that need to be made in the field. Chapters 9 about chemical analysis and 10 about statistical treatment are included to assist the reader acquainted with these subjects and partly to help him/her in the necessary discussions with chemists and mathematicians.

The case histories presented in Chapter 11 have been chosen to illustrate a wide variety of situations: topographies from peneplain to mountains,

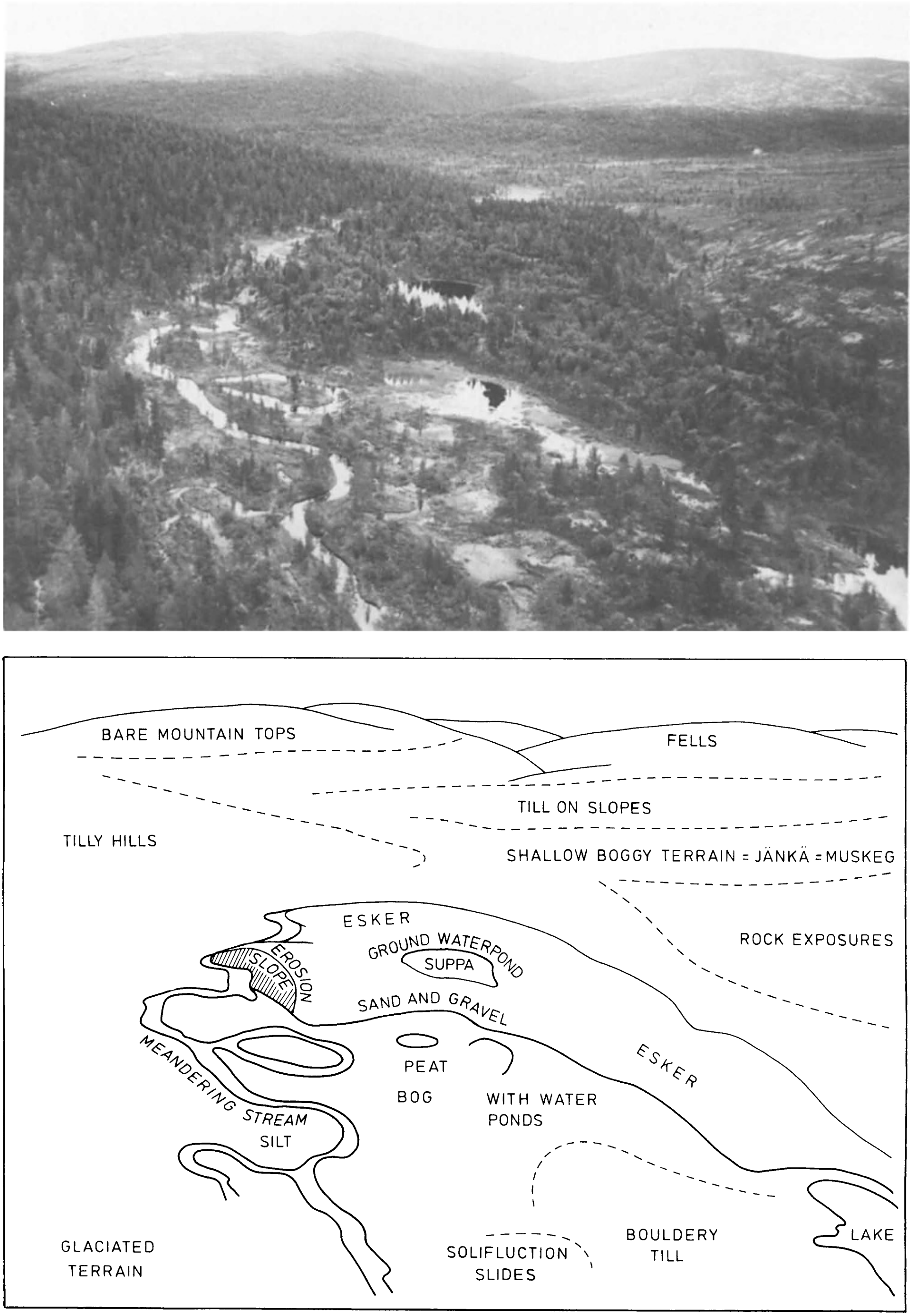

Fig. 1-1. Different types of overburden formations and materials in arctic and temperate glaciated terrain. (photo Peter Johansson)

climate from arctic to temperate, and as many types of overburden as possible. It is to be hoped that from among the many case examples the reader will find at least one closely resembling his or her own research object, and find instruction in how others have proceeded and succeeded, or failed. Besides explaining their particular studies, the authors tell what else should be done and what conclusions can be drawn.

The final Chapter 12 "Focal aspects of soil geochemistry applied in arctic and temperate regions" is not a summary but some kind of overview of the state of art and it is hoped that recommendations given in it will help geologist in the geochemical stage of her/his usually urgent prospecting task.

HISTORY OF SOIL GEOCHEMICAL PROSPECTING

The use of metals, their exploration and the beginning of geochemistry go back a long way. Five thousand years ago, village blacksmiths in India, Iran, Mesopotamia and Greece were acquainted with copper and were able to smelt it with tin to make bronze. Iron was introduced to Greece about 3100 BP and its use had spread to northern Europe by about 2500 BP.

How did our forefathers find their ores before the days of sampling nets and sophisticated analytical instruments? Ancient prospectors were practising a form of geochemical exploration of soil when they searched for copper stain and iron rust. An old tale from Sweden relates how a farmer in Falun was led to an iron ore by a goat that came home with its hoofs coloured red. In the Finnish national epic *Kalevala* it is observed "the birth of iron is of rust".

Georgius Agricola colourfully describes the use of "geochemical" methods of prospecting in his famous book *De Re Metallica* (1556):

> Now I will discuss that kind of minerals for which it is not necessary to dig, because the force of water carries them out of veins. Of these there are two kinds, minerals — and their fragments — and juices. When there are springs at the outcrop of veins from which, as I have already said, the above-mentioned products are emitted, the miner should consider these first, to see whether there are metals or gems mixed with the sand, or whether the waters discharged are filled with juices (quoted by Boyle, 1967).

Jakob Forsskål, Finnish state prospector in the early eighteenth century advises in his book *Om malmers kännande och efterletande. Underrättelse för allmogen och gemene man* (1736), how overburden, water and air should all be taken note of:

> Overburden itself can tell about the ores below or in the vicinity. The weight and colour of such a soil, sand or clay, when carefully studied, usually tell much: green soil or drift points to copper ore, black, red and brown sand or soil to iron, varyingly yellow, white or bluish sand or clay to silver or lead.

He also notes that water which in confined places takes on colour and taste from the surrounding soil "reflects the metalliferous rock through which it is running by its nasty taste and mean flavour," and as the final test "kills the animals drinking it".

Daniel Tilas, another Finnish state geologist, reported in 1743 that ore floats are situated to the southeast side of ore suboutcrops in Finland, so hinting for the first time at the method of boulder tracing. This method of exploration was taken to North America as early as 1747–1751 by Pehr Kalm during his botanical excursions (Goldthwait, 1982). A century later the direct correlation between the chemistry of the overburden and the bedrock below was taken careful note of by Hjalmar Lundbohm (1887) in his studies of Swedish marble formations and the Ca content of the overlying soil.

It was not hard to guess at the origin of ore boulders in talus up on the valley side. As early as 1802 Playfair deduced the activity of valley glaciers in transporting boulders along the valley, and in 1832 Bernhardi traced the source of the big porphyrite and granite erratics in northern Germany back to Scandinavia (Goldthwait, 1982). Nils Nordenskiöld published his map of glacial striae in Finland in 1863. Moving into our own century, boulder tracing for glaciological (Helmersen, 1882; Hedström, 1894; Hausen, 1912) and later for explorational purposes became popular and important not only in Finland but in all northern countries including Canada and the United States (Sauramo, 1924; Högbom, 1931; Lundqvist, 1948; Flint, 1947; Holmes, 1952; Grip, 1953; Aurola, 1955).

Minerals were sought and mined from sediments long before Agricola — for example, by panning of gold and precious stones. Since the gold rushes of last century, the heavy minerals in sediments have been studied worldwide both for prospecting purposes and "mapping" of the underlaying bedrock (e.g., Raeburn and Millner, 1927; Kivekäs, 1946; Mertie, 1954; Theobald, 1957; Theobald and Thompson, 1959; Lee, 1971).

Mineralogical analysis is based on relatively few identified grains that hopefully are typical. If thousands were counted the process would be too time consuming and tedious. A sample of finer fraction analyzed chemically gives more reliable results. The first attempts to use soil chemistry specifically for prospecting were made in the Soviet Union in the 1920s by Vernadskij, Vinogradov and Fersman; the method was called metallometry, and according to the metal sought, cuprometry, ferrometry etc. (Sergeev and Solovov, 1937).

With little delay the chemical method was applied in Norway (Goldschmidt, 1934; Vogt, 1939), Finland (Rankama, 1940; Kauranne, 1951), Canada (Chisholm, 1950) and the United States (Hawkes and Lakin, 1949; Huff, 1951). Rapidly pedogeochemistry, as it was called in the West, spread throughout the world, being successfully applied in a variety of geological environments.

As further examples of earlier case histories in pedogeochemical prospecting, from warmer to cold climate, the following may be mentioned: Hawkes (1952, 1954); Holman and Webb (1957); Webb (1958); Govett (1960); Armour-Brown and Nichol (1970) — Sergeev (1941); Fulton (1950); Huff (1952); Bloom (1955) — White and Allen (1954); Warren and Delavault (1956); Ermengen (1957); Boyle and Cragg (1957); Kauranne (1958, 1959); Dreimanis (1960) — Pitulko (1968); Garrett (1971); Gleeson and Cormier (1971); Shilts (1971); Cameron (1977); DiLabio (1981).

The new method proved successful in tropical and nonglaciated temperate areas, whereas in glaciated terrain there were both successes and failures. The haphazard sampling of glacial overburden produced results of no value to exploration and the financing of pedogeochemical studies ran into difficulties in Soviet Karelia (A.V. Sidorenko, pers. commun., 1978) and Scandinavia. One of the first attempts to apply the methods in Finland was in connection with the search for the source of the Vihanti zinc-bearing boulders, but no obvious anomalies were found (O. Joensuu, unpubl. report, 1947). Later on, the till at Vihanti was shown to be highly complex in structure and material (L.-M. Kauranne, 1979). Failures, of course, are seldom reported in the literature, but plenty of the successful cases of geochemical exploration are described, for example Harbaugh (1953); Ginzburg (1960); Hawkes and Webb (1962); Kvalheim (1967); Levinson (1974); Nichol and Björklund (1973); Siegel (1974); Beus and Grigorian (1977). Other examples are given in the many compilations of international symposia arranged by the Association of Exploration Geochemists and the Institute of Mining and Metallurgy (see works edited by Bradshaw, 1975; Kauranne, 1976a; Björklund, 1984).

Traditions in science and different geological conditions have combined to produce a number of "schools" of geochemistry, e.g., the "French-Soviet" type of geochemistry, centring around the International Association of Geochemistry and Cosmochemistry and including e.g., A.P. Solovov, A.I. Perelman, V.V. Polikarpochkin, J. Barbier and E. Wilhelm, and the "Anglo-Saxon" type of geochemistry, represented by J. Webb, H. Warren, H.E. Hawkes, R.W. Boyle. A.W. Rose, E. Cameron, I. Nichol and G.J.S. Govett. Then there is the "glacigeological" group of geochemists A. Dreimanis, W. Shilts, W. Coker, R. DiLabio and most Fennoscandian researchers. Each group has had its own interests and methods of study and has developed its own terminology. For example, lithogeochemistry in the Soviet school covers all materials consisting of mineral grains, both nonconsolidated overburden and tough rock, while lithogeochemistry in the Anglo-Saxon school is equivalent to rock geochemistry. The joint symposia organized by the various groups have helped to construct a common "language" without which no comparison of achievements is possible.