

# Tectonics and Geological History of some Phanerozoic Orogens

Honorary volume to David G. Gee on the occasion of his 60th birthday

Edited by Björn Sundquist & Michael B. Stephens

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– B.S & M.B.S.

## Foreword

Every science has the occasional fortune that a person emerges who has the imagination, creativity and leadership to initiate and maintain progress in research on a broad, international basis. David G. Gee is such a person. Over several decades, he has played a central role in Swedish and international research in geology. At present, he is the leader of the research programme "Europrobe".

The Geological Society of Sweden owes David a special thanks. During his two and a half years' presidency from May 1988 through 1990, the Society was rejuvenated in several ways. The present issue is a means for the Society to honour David on the occasion of his 60th birthday.

Several colleagues from both Europe and the USA, with whom David has collaborated and/or exchanged ideas over the years, have gathered to present 14 papers within this honorary volume. Following an opening salute by Gunnar Kautsky, the issue addresses most of its attention to aspects of the tectonics and geological history of Palaeozoic orogenic belts in the North Atlantic region, and in the central and eastern parts of Europe. These belts formed during amalgamation of the supercontinent Pangaea. It is within these fields of geology and within this geographical area that David has focussed his skills and enthusiasm for over 35 years. Papers concerned with younger Phanerozoic orogens in the Alps and the Himalayas as well as intraplate compressional deformation complete the issue.

The opening paper updates present views on the Early Ordovician to Mid Devonian palaeogeography in the North Atlantic region (Torsvik). It is followed by two papers concerned with the Appalachian Orogen in the eastern part of North America; a major review of the various tectonothermal events in New England in the northern part of the orogen (Robinson et al.) and the first documentation of Silurian K-bentonites in the Appalachians in eastern USA (Bergström et al.). Attention is subsequently focussed on the Scandinavian Caledonides in the form of three papers. These address, amongst other matters, early rifting (Andréasson et al.), drifting and Lower Palaeozoic faunal provincialism (Cocks & Fortey), and collisional processes (Greiling et al.) around the late Neoproterozoic and Early Palaeozoic continent Baltica. Papers concerned with the orogenic evolution, including extensional detachment systems, in the East Greenland Caledonides (Andresen & Hartz) as well as the timing of high pressure and high temperature metamorphism in the Svalbard Caledonides (Gromet & Gee) follow. The significance of high pressure and ultra-high pressure metamorphism in Phanerozoic orogens, with particular emphasis on models for exhumation of the rocks affected by these processes, is emphasized again in the context of the younger Uralidian and Variscan orogenic belts in the central and eastern parts of Europe (Matte). A new model involving deep, extensional detachment tectonics is presented for Carboniferous-Permian faulting along the northwestern part of the Tornquist Zone (Berthelsen).

Two papers which address, in part, younger Phanerozoic orogens follow. The first of these papers provides a brief overview of erosion in the Himalayan mountain belt (Friend) and is followed by a short, comparative study of the tectonic evolution in the Alpine and Scandinavian Caledonide orogenic systems (Milnes). The issue closes with a paper on the nature and dynamics of intraplate compressional structures which can develop at large distances from collisional plate margins (Ziegler).

We are confident that the papers presented in this issue will provide much stimulating thought not only to David, to whom the issue is dedicated, but also to our interested readers.

*Björn Sundquist & Michael B. Stephens, Editors*  
*Jan Bergström, President of the Geological Society*

# *Tabula gratulatoria*

## *to David G. Gee*

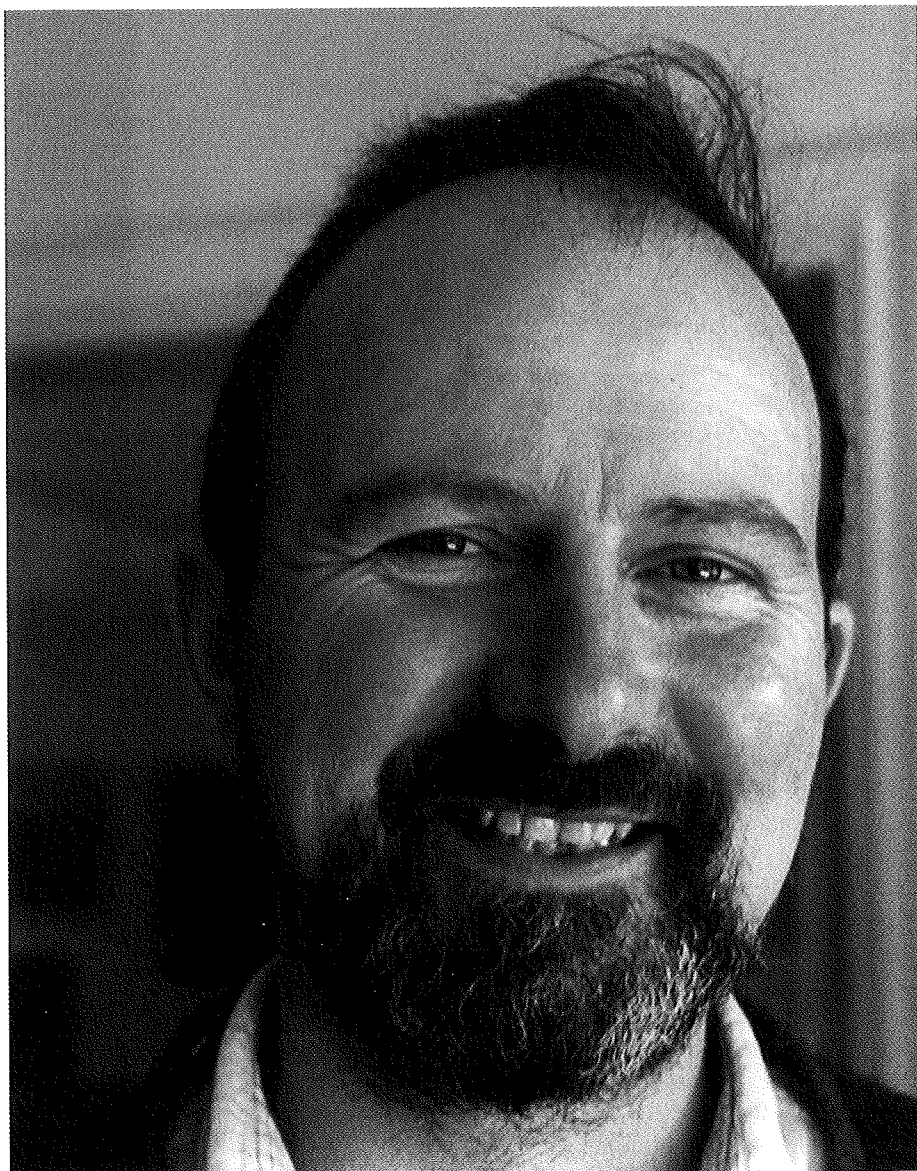
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| Algimantas Grigelis, Vilnius     | Bertil Norrlöf, Molkom         | Ebbe Zachrisson, Uppsala          |
| L. Peter Gromet, Providence      | Jens Ormö, Huddinge            | Peter A. Ziegler, Basel           |
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## Salute to David G. Gee

GUNNAR KAUTSKY

One of the most outstanding persons today in Swedish geology is David G. Gee. He is at present Professor and Dean of the Faculty of Geosciences at Uppsala University. He is also Chairman of the international research programme *Europrobe* and of the Swedish Committee for the *International Lithosphere Programme* (ILP). During the last six years he has led a research group in collaboration with the Swedish Polar Institute working on the Caledonides of Svalbard and related areas around the Barents Sea. He will be the Chairman of the European Union of Geosciences (EUG) meeting 1999 in Strasbourg (France) which will be arranged by Sweden. During his career, David has participated in many important national and international projects. In all of these projects, he has left his trademark and driven geoscience forward. David is unconventional, tolerant, easy to cooperate with and strives to bridge the gap between the different geoscientific disciplines. In spite of being an outspoken field geologist, he now has his office in a geophysical institute. This is very characteristic of this eminent geoscientist.

I will try to describe David's background and career with the support of his Norwegian wife Veslemøy and several of his colleagues including Ebbe Zachrisson, Michael Stephens, Monica Beckholmen and Hermann Zeyen.



### Background

David was born in Sutton, Surrey, England on the 11th December 1937. After spending his early years in India and his later schooling in England, David entered Cambridge University in 1958. In 1959, he travelled for the first time to Svalbard with the British geologist Peter Friend. Every evening when they returned to camp, Peter would discard 99% of the fossils they had collected during the day and David decided then not to become a palaeontologist! He returned to Svalbard in 1961, 1962 and 1963

as part of the Cambridge expedition under the leadership of Brian Harland (his Ph.D. supervisor) and, in 1964 and 1965, he worked part-time for the Norwegian Polar Institute. During this time, he mapped in the northwestern and northeastern parts of Svalbard mainly by boat. Shortly after his marriage to Veslemøy during December 1965, he submitted and successfully defended his Ph.D. thesis entitled "The structural geology of the Biskayerhuken Peninsula, North Spitsbergen".



Fig. 1. David in his favourite environment together with Torgeir Falkum, Norway (left), Henk Zwart, The Netherlands (right) and Gunnar Juve (sitting; at that time employed by SGU). Excursion in the Västerbotten Caledonides, July 1968. Photo E. Zachrisson.

During the early part of 1966, David first came into my focus. There were no positions available at the Norwegian Polar Institute and Tore Gjelsvik, Head of the institute, recommended David to take contact with me at the Geological Survey of Sweden (SGU). We had met the first time in January 1966 at the Nordic Geological Winter Meeting in Åbo (Finland), where David gave an excellent presentation. I was very happy that I could offer him a position as geologist in the Mineral Exploration Division (Malmbyrå) at SGU. At that time, the Mineral Exploration Division was expanding rapidly. The base metal ore deposit at Stekenjokk in the Swedish Caledonides had been shown to be of economic importance. In northern Sweden, the iron ores had been reinvestigated and drilled, and exploration for base metal sulphide deposits had been intensified. Exploration for uranium also had high priority. The geologists responsible for these different projects realized that a good knowledge of the geology was a prerequisite for successful mineral exploration and intensive geological mapping was carried out in northern Sweden. New tools in mineral exploration work had been introduced using geophysics and geochemistry while systematic airborne magnetic and radiometric surveys provided the mapping geologists with important new data which could aid their work.

## David's work in the Scandinavian Caledonides

David was placed in Ebbe Zachrisson's Caledonide unit to remap parts of Västerbotten as an aid in the mineral exploration work in this geological province. Already at the end of the 1960's, his responsibility was extended to northern Jämtland where SGU had taken over exploration for uranium in the Tåsjö area from Atomenergi AB. David became deeply interested in the Cambrian alum shales and the *Dictyonema* horizon at the Cambrian–Ordovician boundary. The uranium-bearing shales also contain large quantities of kerogen. When SGU ceased its work on exploration for uranium, he initiated investigations on the kerogen content in the Swedish shales together with Astrid Andersson and Bertil Dahlman. This work was not restricted to the Swedish occurrences but included comparisons with similar deposits in other parts of the world, e.g. the Chattanooga shales in the USA. In many areas, work proceeded along the border to Norway and much work was also carried out in Norway in order to gain a complete regional picture of the geology in the area and thereby solve critical geological relationships. Together with Ebbe Zachrisson, David instructed university students who were temporally employed at SGU during the field seasons in the practical aspects of field geology and tectonics. A large number of young geologists were engaged. Many of these students later completed Ph.D. studies related to these activities and have made use of what they learned during the years working in the Caledonides for SGU as parts of international projects.

In my opinion, the broad international contacts established at SGU's Mineral Exploration Division, based on a long tradition in geological cooperation with other countries, played a major impact on David's career. There had been decades of intensive work in the framework of projects concerned with the Geological Map of the World and cooperation with our neighbours, the Geological Surveys of Finland, Denmark and Norway. In 1960, the Nordic Geological Surveys had together arranged the 21st International Geological Congress in Copenhagen, with excursions in all the Nordic countries which often transected national boundaries. It should be mentioned that the International Union of Geological Sciences (IUGS) was established during the Copenhagen Congress.

The International Geological Correlation Programme (IGCP) had started in the 1960's and both Norway and Sweden had applied during the 1970's for the project "Correlation of Caledonian Stratabound Sulphide Deposits" (CCSS) which became a flagship in IGCP's earlier history. Norway, Sweden, Denmark, Britain, Ireland, USA, Canada and France participated in this project. It ran simultaneously with the IGCP project "Caledonide Orogen" (CO). Both projects created a number of international workshops, symposia and excursions in the Lower Palaeozoic orogens in USA, Canada, Britain, Ireland, Greenland and Scandinavia. International close cooperation was established between leading scientists in these countries resulting in many joint publications. David became a key person in these activities, particularly in the IGCP-CO project. He not only presented his own results at the meetings but also displayed a unique ability to analyse the results of his collaborators in a larger, regional context.

One of David's many publications in international journals,

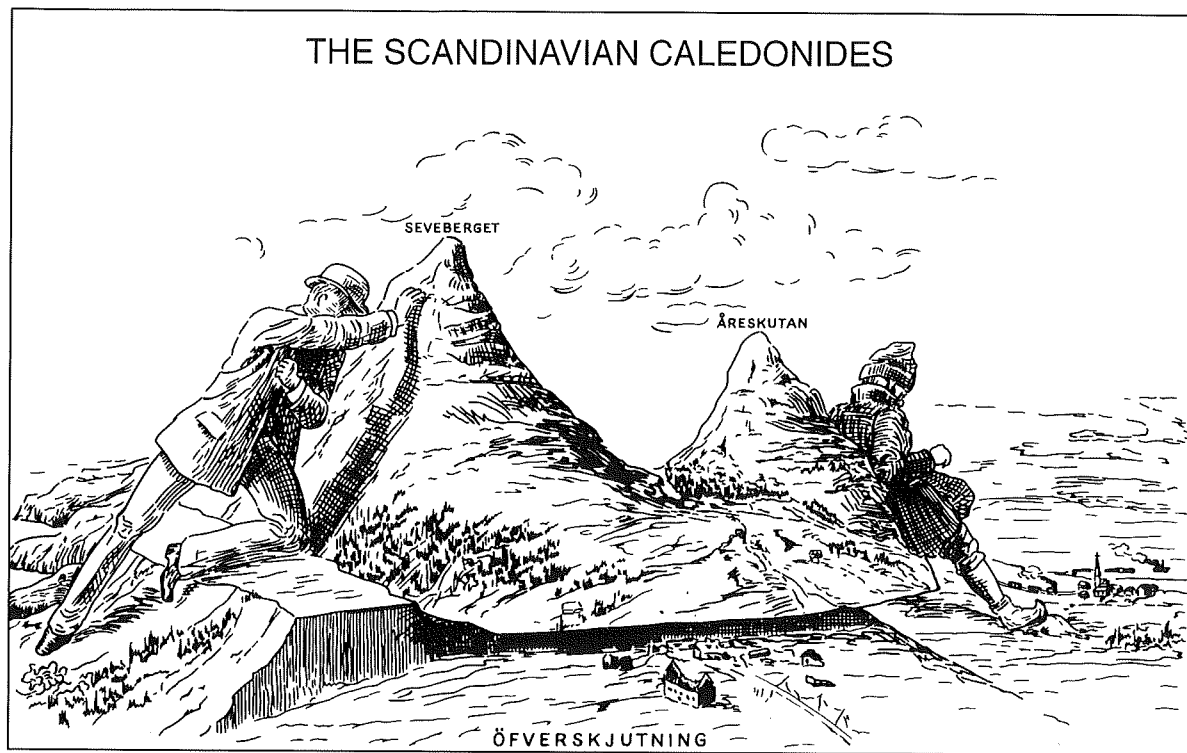


Fig. 2. The Caledonian controversy towards the end of the 19th century, personified in A.E. Törnebohm to the left and F. Svenonius to the right. The cartoon was redrawn by S. Järnefors from the original by E. Erdmann (alias En Elak), drafted by P. Röding and circulated at the celebration of the 25th anniversary of the Geological Society in 1896.

"A tectonic model for the central part of the Scandinavian Caledonides" (American Journal Science, 1975), made a major impact on our understanding of the Caledonides in Scandinavia. This paper presented the orogenic belt in a much broader context and was a major breakthrough for the application of plate tectonics in Scandinavia. A major event in international cooperation was a symposium (with excursions) under the auspices of the IGCP-CO project which took place in Uppsala (Sweden) during 1981, with more than 400 participants from all over the world. The meeting was a major scientific success. During the symposium and excursions, participants started to realize how the Scandinavian Caledonides had formed step by step as well as how and when different "exotic" pieces had accreted both to each other and to the margin of Baltica. There was no longer a Norwegian *contra* a Swedish model. There was now a single model for the Scandinavian Caledonides. Even from the social point of view the meeting was a major success, the symposium dinner being served in the old castle in Uppsala.

It was decided to present the results of the Uppsala symposium in a monograph with contributions from the participating scientists. David and Brian Sturt (Geological Survey of Norway, at that time active at the University of Bergen) edited the 84 contributions which provided an overview of the Caledonide Orogen in mainland Europe, Svalbard, Greenland and North America. The results were published in 1985 in two volumes (1255 pages with maps in a special envelope) entitled *The Caledonide Orogen—Scandinavia and Related Areas*. From this date, the name

of David G. Gee was well established in Scandinavia, North America, Britain and Ireland.

From the beginning of his work in Jämtland, David was an admirer of Alfred Elis Törnebohm who, as early as 1886, had published sections through the Scandinavian Caledonides which displayed the Seve Nappes with their high-grade metamorphic rocks thrust from the northwest over low-grade metamorphic rocks to the southeast. Törnebohm calculated that low-angle movement along low-angle thrusts in the Scandinavian Caledonides was two or three times greater than the movement calculated along the thrusts in the Alpine orogenic belt. Törnebohm's ideas provoked major discussion in Sweden but did not arouse international attention as his results were published in Swedish. Törnebohm's main antagonist at that time was the Swedish geologist Fredrik Svenonius who didn't believe in thrusting. David often started his presentations of the tectonics in the Scandinavian Caledonides with a picture showing Törnebohm trying to thrust the mountains from the northwest and Svenonius pushing against (Fig. 2). It is amazing to see how valid, even in detail, Törnebohm's views have proven to be, 100 years after their original presentation. Törnebohm's tectonic concepts for the Caledonides were contemporaneous with or even earlier than the thrust theories in the Alpine orogenic belt put forward by Swiss and French geologists. David made Törnebohm known all over the world among geologists working with orogenic belts. He also organized a Törnebohm memorial symposium entitled "Thrust tectonics in Fennoscandia" in Lund during 1988.



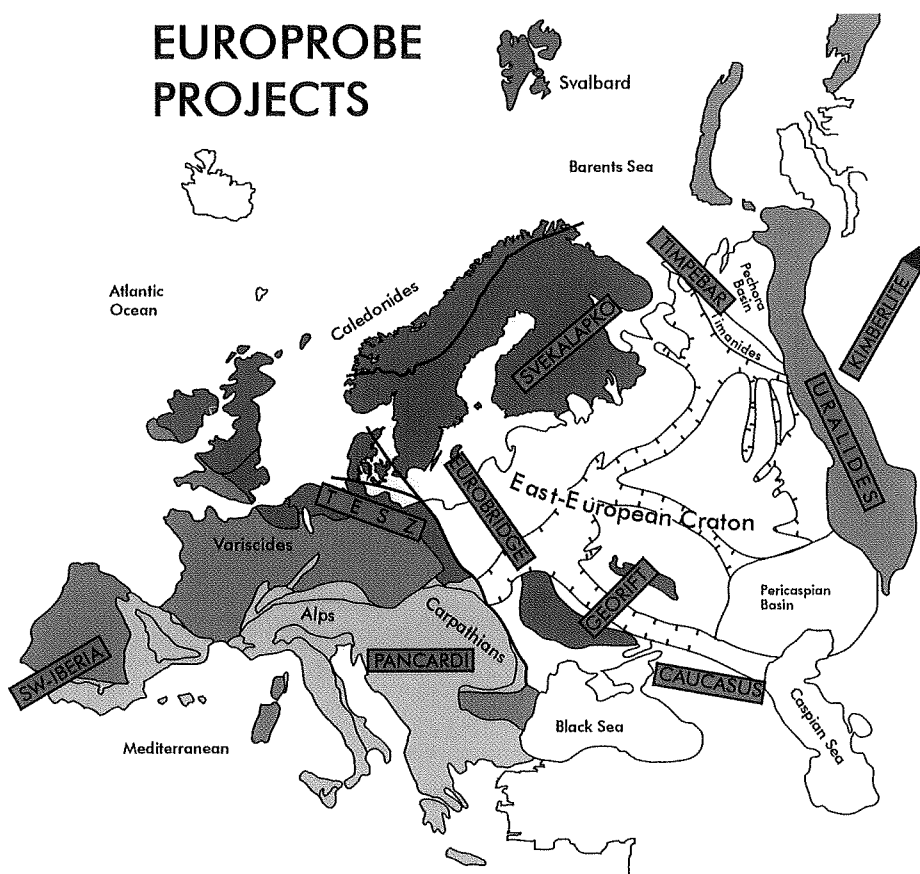


Fig. 3. Geological research areas and sub-projects of the Europrobe project. Courtesy: Europrobe Secretariate, Uppsala, Sweden.

## David's work with the integration of geology and geophysics

The 24th International Geological Congress 1972 in Montreal (Canada) had an important influence on David's future relationship with the discipline of geophysics. Several of SGU's exploration geologists participated in the congress to learn about Canadian geology and mineral deposits which have strong affinities to the Scandinavian equivalents. David was one of those who attended the congress in Montreal. He had chosen an excursion through the Rocky Mountains west of Calgary. During this time, the oil companies working in the frontal part of the Rocky Mountains had released much information concerning deep reflection seismic surveys for oil exploration. It was an outstanding material showing deep seismic sections through the Rocky Mountains, a mountain range of alpine age. Like the Scandinavian Caledonides in Sweden, the Rocky Mountains consist of a pile of thrust sheets which were emplaced from west to east over a foreland, in Canada with thick sedimentary cover containing oil. The deep seismic sections showed very clearly the complete geological picture with great accuracy; the basal décollement, the thickness, form and dip of the nappes, tectonic fishes, etc. I myself joined an excursion along a geological transect from Calgary westwards through the Rockies and several terranes ending at Vancouver Island on the Pacific coast. This trip was led by Jim Monger from the Vancouver branch of the Geological Survey of Canada and demonstrated the same type of deep seismic information. When I met David some weeks later he was extremely

enthusiastic. "We should have such seismic sections in Jämtland to solve the mysteries of the Caledonides", he shouted. We both agreed that deep seismic surveys are very expensive and complained that there is no oil in the foreland of the Caledonides in Sweden. It was also necessary to convince geophysicists running deep seismic surveys of the importance to solve structural problems at higher crustal levels, not only to look for the Moho and even deeper parts of mother Earth. Geophysicists can then appreciate that an understanding of geological features near the Earth's surface is necessary to solve geophysical problems at depth and *vice versa*. Well, that was in 1972. It also turned out to be good timing. Worldwide geophysical-geological cooperation had started some years earlier

in the shape of the "International Geodynamics Project". This was the first joint venture between the International Union of Geological Sciences (IUGS) and the International Union of Geophysics (IUGG) to obtain better knowledge about the character of the earth's crust and core.

SGU was very interested in taking part in this project in order to support the extensive activities in the Caledonides. At a meeting in Uppsala in 1974 which was attended by representatives from the Swedish universities and SGU and which aimed to discuss how Sweden could participate in this project, David gave an excellent talk about the Scandinavian Caledonides which was enthusiastically received by the people present. This meeting resulted in forming the "Caledonian Research Project" (CRP) as one of the Swedish contributions to the "International Geodynamics Project". It was a 300 km long and 200 km wide geotransverse through the Caledonides from Östersund in the east to the Norwegian coast in the west. This project aimed to integrate geological and geophysical studies. David became a member of the steering group of the "Swedish Geodynamics Project" and was responsible for a variety of research projects not only in Sweden but also in the international arena. SGU had a powerful and competent geophysical unit under the leadership of Sture Werner and David learned very quickly how to use geophysical tools in geological mapping. In particular, when he became involved in the exploration for uranium in the alum shales near Tåsjö in Jämtland, he learned how to use different sophisticated electrical methods in this type of exploration.

In 1983 and 1984, David became a visiting professor at Vir-



ginia Polytechnic Institute in Blacksburg, USA. He returned to Sweden but decided to leave SGU in 1986 in order to take up a personal chair in tectonics awarded by NFR (Swedish Natural Science Research Council). He decided to have his base at Lund University in southern Sweden. The new position allowed him to work intensively within the context of a new international research programme - the "International Lithosphere Programme" (ILP). One of the major projects within this research programme was the "Global Geoscience Transect Project" led by Jim Monger, well known to Scandinavians since the International Geological Congress in Canada 1972. David led an integrated geological and geophysical study along the Östersund-Trondheim transect which now included deep reflection seismic work. Subsequently, he acted as Vice-Chairman for the transects project. As a consequence, he became well known, not only to the people working in the different subprojects within Europe and other continents, but also to the various scientific councils who financed the geoscientific work. He still kept his contact with colleagues at SGU and moved back to Uppsala in 1994, with an office at the Geophysical Institute at Uppsala University.

In 1988, David was appointed Chairman of Europrobe. Karl Fuchs, Karlsruhe (Germany), a well-known geophysicist and at that time President of the International Lithosphere Programme, was appointed Vice-Chairman. Europrobe is an interdisciplinary group of projects that intends to improve our understanding of the tectonic evolution of the Earth's crust and upper mantle and the dynamic processes which control this evolution through time. The interplay of modelling and theory combined with field studies is central. Since 1992, Europrobe is even supported by the European Science Foundation (ESF). Europrobe aims not only to promote collaboration between top scientists but also between different organisations in western, central and eastern Europe and, as shown on Fig. 3, many of the projects are carried out within former Eastern Block countries. About 600 scientists are at present engaged in the projects and meet at 7-9 workshops every year.

Even if not all of the goals of Europrobe are achieved in this on-going collaboration between "eastern" and "western" scientists and organisations, it will mean a major step forward for our knowledge of the geological history and structure of Europe and will provide a much better base for geological models and for our economic evolution. In spite of the difficulties in starting multinational and multidisciplinary projects, nearly all the projects have come off the ground during the last six years. East and west have had to learn how to cooperate, which was an especially difficult task for the local administrators. It was mainly due to David's tenacity and diplomatic skills that Europrobe emerged and obtained international recognition as an umbrella for the European lithosphere investigations. David's and Europrobe's reputation are especially high in eastern Europe where Europrobe is considered vital for the continuity and reconstruction of the geosciences.

## President of the Geological Society of Sweden and ongoing research

From May 1988 through 1990, David was President of the Geological Society of Sweden. During David's chairmanship, the Geological Society changed old routines in favour of whole-day thematic symposia. These addressed ongoing questions of geological character which had also been discussed in the newspapers and on television, such as radioactive waste disposal and the Siljan gas project. It was a major success and the Geological Society of Sweden became rejuvenated and again a panel in Sweden for discussing geological issues and problems.

As leader of major, integrated geological and geophysical enterprises, David's career has become more and more administrative in nature. However, even at 50, he refused to give up field work completely. He remembered his field studies in Svalbard as a young geologist and had learnt a great deal during 20 years of intensive field activities. He now recognized new possibilities for a better understanding of the geological problems of Svalbard in a broader context and once again took up research and mapping for the Norwegian Polar Institute in 1985. Since 1990, he has been working every summer in Svalbard and the Barents Sea area for the Swedish Polar Institute and is planning to include the arctic parts of European Russia in this research. As you can see from his publications, it has been a very productive time for David and his co-workers. This work is still going on and provides a field geological breathing hole in the increasingly time-consuming, administrative duties.

## A final reflection

David now carries a Swedish passport, but he will always remain an Englishman at heart. Perhaps only his closest friends - and family - know that under that polished, British surface lies a vivid imagination and an eruptive temperament. Working and living with David is never dull, frequently taxing, often exhausting, but always rewarding.

When looking back, it is astonishing to see how much David has already achieved during his geological career. But it is far too early to summarize. David is at present leading major international geoscientific enterprises, travelling as hectically as ever, organising symposia, meetings and workshops, encouraging and giving advice where it is needed. Problems between organisations and individuals, which always arise when people and institutions in different countries with different priorities collaborate, need to be resolved. He also plays a leading role to help find the funding for all these broad activities. Major progress is at present being achieved and I feel that David has the power, skills and tenacity to realize his visions in the years that lie in front of us.

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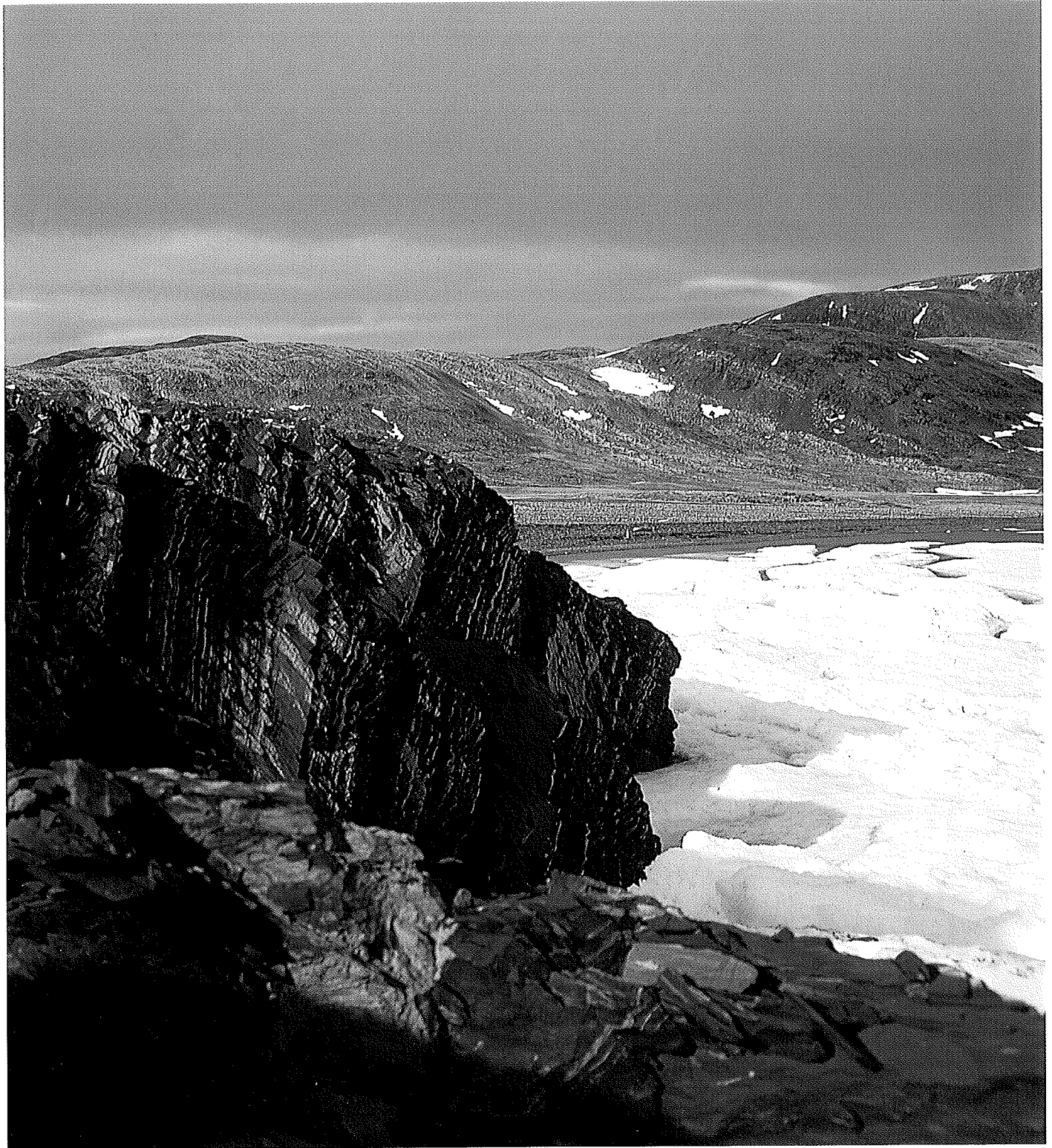
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