Organisational bonus through staff rejuvenation: Greenland – Australia exchange

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Advances in geoscientific research are more than ever before dependent on international teamwork. Concurrently with this increased co-operation, geological surveys the world over are becoming more and more international in outlook. Stimulated by government initiatives, modern geological surveys, both national and state, are committed towards greater customer focus. Not only are work programmes now specifically designed to encourage commercial investment by directly meeting the needs of industry, but geological surveys are widening their scope and image by undertaking activities abroad. Apart from the scientific advantages of international co-operation and the added incentives of staff training and development, involvement in foreign projects is arguably part of a Survey's political responsibility in assisting developing countries.

This introductory statement applies equally well to the newly constituted Geological Survey of Denmark and Greenland based in Copenhagen, as to the Geological Survey of Western Australia, 15 000 km away in the southern hemisphere, with headquarters in Perth. Survey activities abroad range in scale and type from the engagement of geoscientific teams carrying out specific tasks on contract, with the periodic stationing of personnel abroad, to the technical exchange of expertise and advice on a personal level.

This paper deals with an example of a short-term staff exchange (9 months) between Copenhagen and Perth, and the benefits gained, both on organisational and individual levels. The authors, as participants in this exchange, were engaged in their host country on projects involved with the study and mapping of Precambrian complexes (Guj, 1995). Thus, the theme of this paper is mainly concerned with Precambrian geology, although the general premises discussed may equally apply to other geological fields.

The 1994–95 exchange: field season, conditions and survey reorganisation

The exchange took place between June 1994 and April 1995. Built into the programme was one season's field work, participation in a team project, with enough time available to work on and write up the main results. Although dealing with regions in opposite hemispheres, the normal field seasons in the two lands are broadly concurrent. Both are constrained by the climate: in Greenland by the cold, snow and darkness of winter; in Western Australia by the heat of summer.

Important premises behind the exchange were that the participants should be permanent Survey employees with several years seniority and of broadly similar status. Conditions were thus optimal to ensure that the expertise offered to both organisations would be comparable, and that the experiences gained would be transferred back to the home organisation.

It so happened that political initiatives determined that in 1994–95 the geological surveys in Copenhagen and Perth were undergoing change. During the period of the exchange, the Geological Survey of Greenland was involved in discussions about the merger with the larger Geological Survey of Denmark and about the future relationship to the Greenland Home Rule Government (Ghisler, 1995). On the other hand, the Geological Survey of Western Australia was undergoing reorganisation and expansion. This was the result of the incorporation of the cartographical mapping branch, and the addition of contract staff into new programmes introduced through extra governmental funding which aimed to stimulate investment in exploration (Guj, 1994). These developments gave a much closer insight into the organisation of 'state-run geology' in our host country than otherwise would have been the case.

Greenland and Western Australia: similarities and contrasts

Greenland and Western Australia have a comparable size and geological make-up. Western Australia has an area of 2.5 mill. km^2 against Greenland's 2.2 mill. km^2 (Fig. 1), and both regions have a fairly complete geological column from the Precambrian to Cainozoic. Permanent ice covers about 80% of Greenland; some 90% of Western Australia has a deeply weathered regolith cover. Of particular note is the fact that the geological history of both countries goes back to the earliest Archaean with the Nuuk region of West Greenland and the Yilgarn Craton of Western Australia (Fig. 1) having for many years competed for the tag of sporting the world's oldest rocks; this position is now held by the Slave province of Canada with the 4.0 Ga Acasta gneiss.

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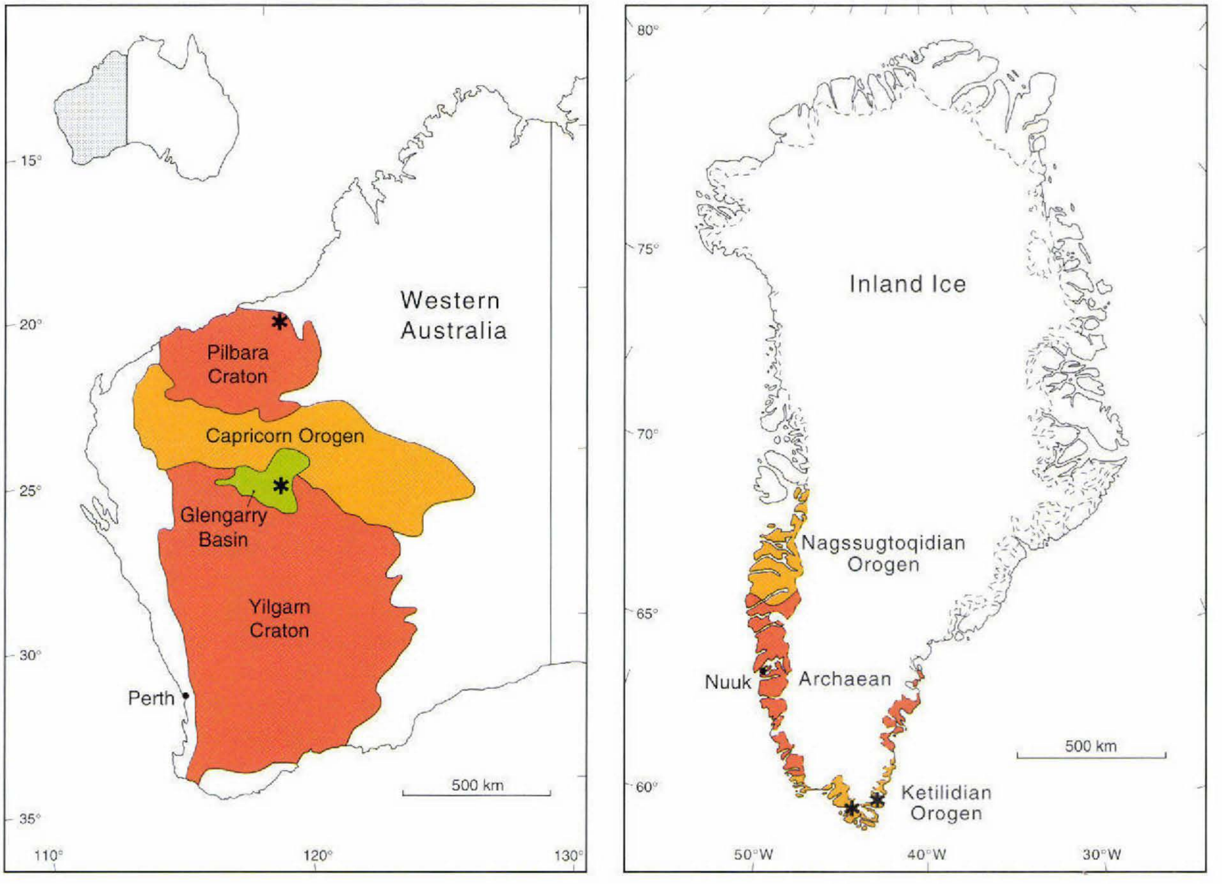

Fig. 1. Location maps of Greenland and Western Australia at the same scale. Stars locate the field areas studied during the exchange.

The Precambrian geology of Greenland and Western Australia have been the subject of comparative studies (e. g. Nutman, 1991), and both regions have contributed to the understanding of the evolution and assembly of Precambrian gneiss terranes and in unravelling the Earth's earliest history. Early to Late Proterozoic sedimentary and volcanic successions are also well represented in both countries. Recent research suggests that the Precambrian crust of Greenland and Western Australia evolved spatially much closer than the present-day geography might suggest. Based on the similar Proterozoic crustal evolution and metallogeny, recent supercontinent reconstructions favour the amalgamation of Laurentia and Australasia, with North America being juxtaposed off eastern Australia (Hoffman, 1991; Young, 1992).

Late Proterozoic glacial deposits are preserved in both countries, and followed by thick Phanerozoic successions in which Palaeozoic, Mesozoic and Cainozoic sequences are present. These sequences occur both as undeformed platform cover and within orogenic belts. In Western Australia Phanerozoic rocks compose more than 50% of the country; in Greenland about 30%.

Apart from the obvious geographical differences between Greenland and Western Australia – ice and an arctic climate versus a laterite-covered arid region – a fundamental difference concerns the role played by geology in the economic development of the two lands. Considering their similar geological make-up, this is enigmatic. Mining is an important part of everyday life and the backbone of Western Australia's economy. Of the wide range of commodities mined – gold, iron ore, nickel, bauxite/alumina, titanium minerals, salt, diamonds, petroleum/gas, coal, manganese, base metals (just to name the most important) – many represent major sources on a world scale. In stark contrast, Greenland, at the present time, has no mining industry. In the light of this sombre difference, Australian expertise must be welcome in any exploration and mineral assessment in Greenland.

Other notable geo-contrasts between Greenland and Western Australia are in physiography, rock exposure and commercial exploration. In Western Australia, where the majority of the landscape is flat to moderately undulating, the bedrock is poorly exposed and mostly concealed by a variable regolith and woodland to scrub vegetation

(Fig. 2A). The rocks are, however, generally well mineralised and, as a requisite for a thriving mining industry, there is a high level of mineral exploration. In contrast, Greenland with its rugged, in places alpine, topography and indented coast and deep fjords offers some of the best rock exposures in the world, where ice-cleaned surfaces reveal spectacular large-scale geological relationships and clear rock detail (Fig. 2B). However, comparable rock formations to those of Western Australia apparently contain scarce mineralisation (at least at outcrop level) and commercial exploration is at a relatively low level.

Mineable deposits, both near-surface and blind ore bodies, are still being discovered in Western Australia in both poorly explored areas and in the historical mining districts that have been exploited since the last century. Western Australia, unlike Greenland, is covered by standard geophysical maps; a requisite for modern exploration. The well-exposed Greenland outcrops, classified as barren by first-time mapping and exploration programmes, may prove otherwise when studied in the next round of exploration that includes probing the sub-surface. Seen against the claim of Australian metallurgists that Western Australia has still underexplored, even virgin, territory (Guj *et al.*, 1995), the mineral exploration of Greenland is in its early infancy.

Exchange potential

Addition of foreign expertise must be a benefit to any geological organisation; when in the form of an exchange there are incentives to be gained through the new experiences filtered back to the home organisation by mutual training of staff. Seen against the background discussed above – similar geology but basic differences in physiography, rock exposure and commercial exploration – staff exchanges between Greenland and Australia have interesting potential.

Greenland geologists, experienced in working with well-exposed geology and continuous outcrop, can assist in the interpretation of complex bedrock geology in areas of sporadic to extremely poor outcrop. Specific topics might be, for example, the relationships between granites, gneisses, migmatites and supracrustal rocks, or the intricate facies associations of sedimentary basins. In Greenland the nature of granite-greenstone, infracrustal-supracrustal and lithostratigraphic relationships are often determinable directly in outcrop, and the passage from granite and sediment into, respectively, orthogneiss and paragneiss can often be walked out on the ground. In some regions, the boundaries of orogenic belts are there to be seen and photographed; for example, the now classical southern boundary of the Early Proterozoic Nagssugtoqidian Orogen of West Greenland, where the progressive deformation and metamorphism of country rocks and basic dykes can be followed in ice-polished fjord walls (Ramberg, 1949).

Conversely, Australian geologists, with experience in mapping mineralised rocks and in metallogenetic modelling, are well equipped to contribute to the evaluation of the mineral resource potential of Greenland's presently non-productive terrains. Are these terrains really less mineralised, or simply underexplored? How far is the comparatively rare mineralisation due to depth of exposure? Based on present knowledge of mineralisation styles, in which direction should renewed exploration in Greenland take?

In terms of training, Greenland geologists would gain experience in the standard use of geophysical techniques and satellite imagery in the mapping of concealed bedrock, as well as gaining insight into the wide range of styles of mineralisation present in Australian rocks. On the other hand, geologists returning to the mapping of regolith-covered terrains, would have first-hand knowledge of continuous structure and rock relationships, seen potentially in both horizontal and vertical planes. In many parts of Greenland, exposures with a relief of 1000 m are common; in parts of East and South Greenland relief is 2000 m or greater (Fig. 2B). In such areas there is ample scope to integrate detailed structural observations made on a local scale with rock types and structures seen in large-scale continuous sections. This experience is of some relevance when confronted only with data from restricted outcrops (as is often the case in Western Australia, Fig. 2A) from which regional interpretations have to be made.

Field work in Australia and results

Field work by PRD was on two projects, as well as participation in excursions to operational mines. The main field work was conducted between July and October in four periods, with intervals back in the office in Perth. Travel in the field was by four-wheel drive vehicle and for most of the time with field assistant Eugene Carew.

The Glengarry project

This project involves the 1:100 000 mapping of Early Proterozoic sedimentary and mafic volcanic and subvolcanic rocks of the Glengarry Basin on the northern margin of the Yilgarn Craton (Fig. 1). The rocks were deformed and metamorphosed at low grade during the collision of the Yilgarn and Pilbara Cratons that formed the Early Proterozoic Capricorn Orogen. The Glengarry project, initiated late in 1993 as one of several new projects requested by industry, has the aim of mapping the entire Glengarry Basin (Pirajno, 1995). As part of a team of five, PRD's responsibility was the mapping and compilation of the northern part of the Mount Bartle 1:100 000 sheet, producing an explanatory text, and contributing to a new stratigraphic framework for the Glengarry region (Dawes & Le Blanc Smith, 1995; Grey *et al.*, 1995; Dawes *et al.*, in press).

The Yarrie - Shay Gap project

This project comprised a 10-day investigation of Archaean granite-greenstone contacts in the region around the iron-ore opencut mines at Yarrie and Shay Gap in the north-eastern part of the Pilbara Craton (Fig. 1). Accompanied by Survey geologist R. H. Smithies, the work was carried out in co-operation with geologists from the Broken Hill Proprietary Co. Ltd (BHP) mine at Yarrie. The field work established that the contact between granite batholiths and the banded iron-formation of the Gorge Creek Group represents an unconformity and not, as previously thought, a case of granite intruding the sedimentary succession. The documented hiatus, probably of Early Archaean age, has regionalz implications for the interpretation of other granite-greenstone contacts elsewhere in the north-eastern Pilbara (Dawes *et al.*, 1995a, b; Smithies & Dawes, in press).

Field work in Greenland and results

Field work undertaken by CPS was part of the SUPRASYD project investigating the Ketilidian Orogen of South Greenland. In 1994, work was concentrated on both the south-east and south-west coasts of Greenland (Fig. 1). The field work, carried out in a 7-week period in July and August, was by 2-man teams supported by helicopter. Eight geologists took part in the field operation (Garde & Schønwandt, 1995).

The SUPRASYD project

This project, started in 1992, is part of the Survey's long-term mineral resource evaluation programme (Dawes & Schønwandt, 1992). The main aim of the project is a reassessment of the tectonic setting and mineral potential of the Early Proterozoic Ketilidian Orogen, particularly the lesser known and more inaccessible region along the south-east coast of Greenland. The project field work commenced in 1992 (Nielsen *et al.*, 1993).

Mapping work on the south-east coast of Greenland by CPS, accompanied by Tom Frisch, was on the Lindenow Fjord 1:100 000 sheet and placed emphasis on structural analysis of gneisses and high-grade supracrustal rocks. This contributed to the compilation of a provisional 1:100 000 map with explanatory notes (Swager *et al.*, 1995). On the south-west coast of Greenland a shorter period was spent, together with Bjørn Thomassen, in mapping and investigating the ore geology and mineral potential of migmatitic supracrustal rocks adjacent to the Julianehåb batholith. An alternative plate tectonic model for the Ketilidian Orogen emerged from the work, in which the well-known gold mineralisation is related to shear zones active in a back-arc basin (Chadwick *et al.*, 1995; Stendal & Swager, 1995).

Conclusions

The exchange in focus here is a small example or test case of what is possible to achieve on short-term work abroad. Participation in the exchange presented a chance to undertake geological research free from administrative duties, on a different supercontinent (Laurentia versus Gondwana), with new colleagues in a different team framework, and under a complete contrast of climatic, physiographic and logistic conditions. While the major processes of Precambrian geology and the resultant make-up of the shield in Greenland and Western Australia are largely comparable, the different physical conditions provide a real challenge on how to tackle exploration and mapping. The experiences of geological mapping in Greenland and Australia are ideally suited to assist in solving each others specific geological problems.

Greenland and Western Australia have equally diverse geology; Western Australia has diverse mineral productivity as well. The geological surveys of both countries are committed to mapping, recording and interpreting the geology of their territories, and bringing this information effectively to industry and the people who need it. With the vivid contrast in status of mineral exploration and mining in the two countries, it has been rewarding to see how these aims are being achieved by our host organisations.

Final comment

The final comment records the satisfaction of gaining further geological training and experience with a foreign organisation, without the necessity of changing place of permanent employment. Personal rejuvenation is an important aspect of staff development and job satisfaction, and a recommended part of modern personnel management.

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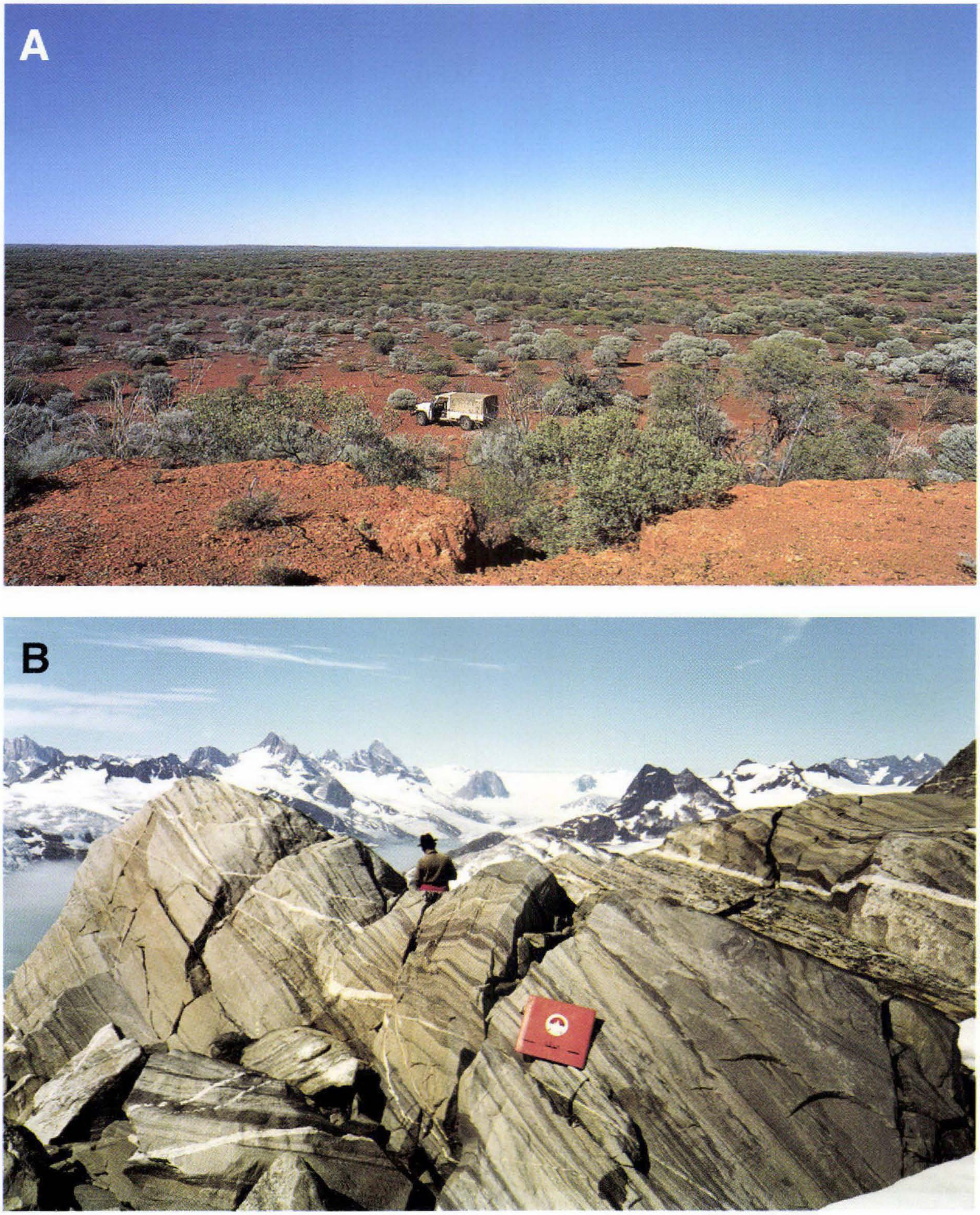

Fig. 2. Contrasts in topography and rock exposure in the Early Proterozoic of Western Australia and Greenland. A: Brown laterite-covered bush landscape of the Glengarry Basin, with main outcrops in low-relief breakaway scarps as in foreground and on the horizon. Kimberley Range, Meekatharra District. Photo: P. R. Dawes, October 1994. B: Clean exposures and alpine topography in the Ketilidian orogenic belt. Psammitic metasedimentary rocks in the foreground; in the background, great relief with the most prominent peak more than 2500 m a.s.l. View is south-west across Danell Fjord. Photo: Bjørn Thomassen, July 1994.

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