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Per Ahlberg, Göran Bylund and Kent Larsson

The geological fieldwork carried out during the Swedish Antarctic expedition, SWEDARP 1991/92, forms part of a research programme aiming at a better understanding of the Phanerozoic geology of western Dronning Maud Land. Previous fieldwork has been performed in the nunatak ranges of Vestfjella and Heimefrontfjella, where mainly the Permo-Carboniferous sedimentary geology has been investigated (Larsson & Bylund 1988, Larsson 1990, 1991). The third major area with sedimentary rocks of comparable age occurs at Kirwanveggen, which was the target for the 1991/92 fieldwork. The aim of this part of the research programme was to (a) study the development of the Permo-Carboniferous sedimentary sequence; (b) to investigate the palaeomagnetic nature of the superimposed volcanics; and (c) to make a preliminary study of the Urfjell Group, of presumed early Palaeozoic age.

Logistics

The Kirwanveggen area was approached on 12 December 1991 via a new oversnow route which mainly runs along the 74th parallel from the main route between Heimefrontfjella and the German Georg von Neumayer station. The camp was established on the southeastern slope of Frostbite Bluff (Figure 1) from where the adjacent nunataks were easily visited by snowmobiles. The northernmost area visited, e.g. the Urfjell area, was approached by helicopters. The camp was abandoned on 27 January 1992. During the entire field season the weather conditions were mainly favourable and only seven days were lost due to bad weather.

The Amelang Plateau Formation

A basic stratigraphy of the sedimentary sequence has been established by Wolmarans and Kent (1982). Our fieldwork has shown that their stratigraphy is well founded. It is followed in this report with some modifications.

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The main distribution of the formation occurs in the southwestern part of Kirwanveggen, where the best developed sequences are found at Frostbite Bluff, Mt. Alex du Toit, Concretion Point and Petrel Peak (Figure 1). Additional outcrops occur at one nunatak further to the south, i.e. the western and eastern escarpments of Mt. Lund, at Ladneset and Ladgaveln in Ladfjella and at Tunga in the Urfjell area (Figure 1). The latter outcrops are small or unfavourably exposed on vertical cliffs, which make approaches difficult. These exposures were examined from helicopter and it is our opinion that they would give few, if any, additional information on the stratigraphy and facial development.

The stratigraphical and sedimentological nature of the examined rocks is shown in Figure 2. The sequence has been divided into four preliminary units. The lowermost unit, "A", exhibits a clear glacial development with tillites resting on a basement of strongly foliated gneisses or schists. The foliation shows dips of 20° to 45° towards 225°. The tillites vary in thickness considerably, i.e. from 0 to 3 metres, and fill

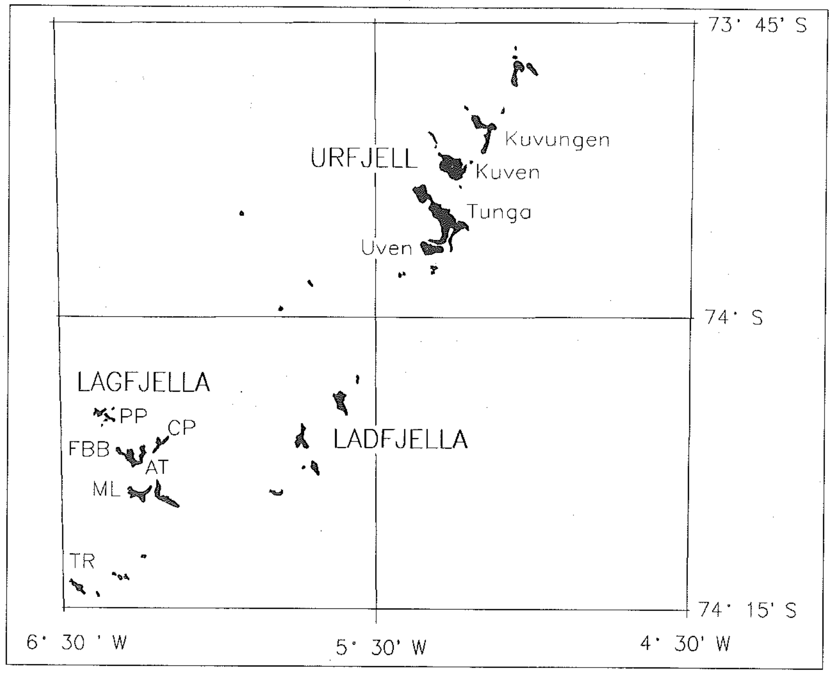

Figure 1. Map of exposed rocks in the southernmost Kirwanveggen area. AT= Mt. Alex du Toit, CP= Concretion Point, FBB= Frostbite Bluff, ML= Mt. Lund, PP= Petrel Peak, TR= Turnaround Ridge.

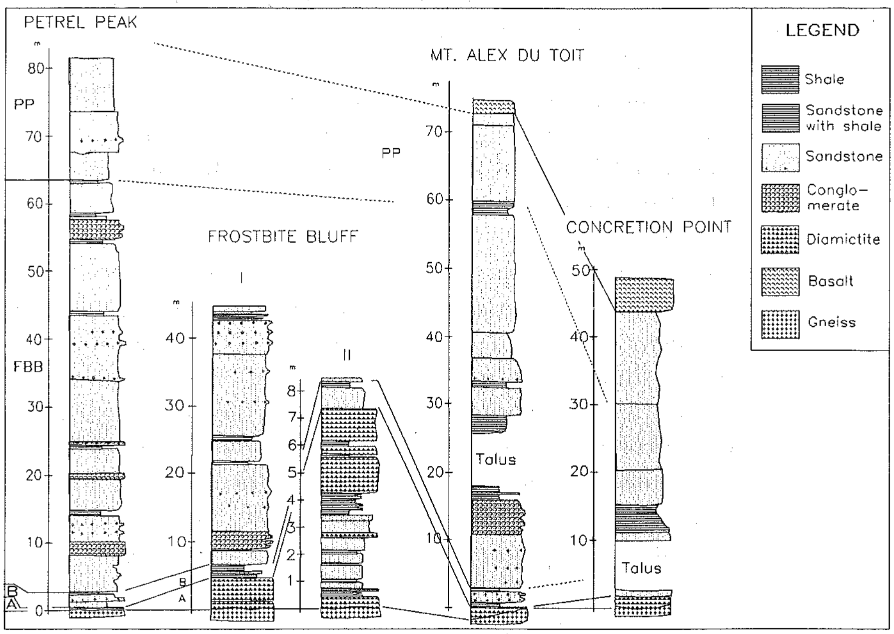

Figure 2. Schematic representation of investigated sections at Petrel Peak, Frostbite Bluff, Mt. Alex du Toit, and Concretion Point. Section II at Frostbite Bluff, at different scale, demonstrates an abnormal development of the glacial sequence. FBB= Frostbite Bluff Member, PP= Petrel Peak Member.

local depressions in the basement rocks. At the northern slope of Frostbite Bluff, six different tillite horizons can be distinguished. These tillites are separated by thin glaciofluvial silt- and sandstones and dark shales. The latter occasionally show varves. The lowermost tillite contains mainly local boulder material, i.e. angular gneiss boulders, while the higher tillites contain mainly subangular to subrounded quartz and quartzite pebbles.

The fabric of the tillites suggests a flow direction towards south-southwest of the ice. The interfoliated stratified rocks show various sedimentary structures, e.g. cross-bedding and ripples indicating a flow direction towards 225°. Some black shales contain abundant plant remains and coal seams are developed locally. Trace fossils can be seen on many bedding surfaces.

The next unit, "B", forms a well stratified shale, c. 1 metre thick, which varies strongly in red, yellow, green and black colours. This member is well exposed at Frostbite Bluff and Mt. Alex du Toit and has yielded an abundant fossil flora.

The superimposed unit, the Frostbite Bluff Member, forms the thickest unit of the area and can be well studied at all visited nunataks, except for Concretion Point, where it is essentially covered by talus material and probably also is thinner compared to the other sections.

This unit is mainly composed of coarse quartz sandstones with abundant feldspar pebbles and conglomerates. The latter occasionally form well defined-horizons which can be traced for considerable distances. The member attains a thickness of 38 metres at Frostbite Bluff, where the top of the unit is truncated, and 60 metres at Petrel Peak, where the contact towards the superimposed Petrel Peak Member is exposed. At Mt. Alex du Toit it seems to attain a thickness similar to that of Frostbite Bluff, but it also varies in thickness locally, the exact amount being difficult to assess due to coverage of talus material. The sandstones of the Frostbite Bluff Member are clearly cross-bedded suggesting a transport

Figure 3. One of the highlights of the expedition was when Kent Larsson found the vertebrate bones at Concretion Point. Photo: Per Ahlberg.

direction towards 225°. Ripple surfaces and current lineations are abundant, which also show a flow towards the same direction. The unit is intercalated by four major shale horizons, which have yielded prolific plant remains. Poorly preserved plant trunks and leaves can also be found in the coarser sandstones.

The youngest sedimentary unit of the Amelang Plateau Formation is the Petrel Peak Member. This unit can be well studied at its type locality Petrel Peak, but also on the western and southwestern side of Mt. Alex du Toit and at Concretion Point. The strata are rather homogeneous with grey to greyish yellow fine-grained sandstones and siltstones. At Mt. Alex du Toit and Concretion Point, the lower part of the unit is red-coloured. Cross-bedding structures and other sedimentary structures such as load casts and current lineations are occasionally well developed and show a flow direction towards 135°. Concretions are abundant forming 5 to 10 cm thick ferrugenous nodules. Poorly preserved plant remains occur in the lower part of the unit. One spectacular find of vertebrate bones was made in this unit at Concretion Point, c. 10 metres below the contact towards the superimposed volcanics. The bone remains were found *in situ* on a surface of 5 metres size and also in weathered sand below this surface (Figure 3). At this stage nothing can be said about their zoological affinity except for their true vertebrate nature.

Depositional environment of the Amelang Plateau Formation

Flow features in the tillites and sedimentary structures in the sandstones show a close correlation to the structural arrangement of the basement. It may be assumed that lineaments in the basement have favoured the formation of valleys trending towards southwest, in which glaciers have formed and sheets of tills have been deposited. These glaciers have made several advances as shown by the different tillites which have filled local depressions. Englacial melting has obviously taken place with deposition of clay and silt between the moraine sheets, but it is also clear that the glaciers have retracted occasionally resulting in deposition of fine-grained melt-out material. Some of the laminated shales show a cyclical deposition of graded laminae, which could represent annual varves.

The superimposed unit B shows no signs of glacial influence. On the contrary, temperate conditions seem to have been prevailing as suggested by the content of plant remains in these shales. Occasionally, these remains have accumulated to form proper coal seams.

The succeeding unit, the Frostbite Bluff Member, is entirely fluviatile with depositional structures suggesting a braided-river system, where sand, silt and rubble alternate rapidly in lateral directions. Occasionally, the fluviatile regime has halted and quiet-water conditions have been established with clay deposition and plant growth. Today, these sediments are seen as 10 to 30 cm thick grey shales. The braided-river deposits have gradually filled out the topographical lows and new flow conditions have formed resulting in the deposition of the Petrel Peak Member. The sediments of this unit have been transported towards southeast under moderate flow regimes.

The arenaceous material of these strata generally show a higher degree of sorting. Possibly, a depositional break has taken place in the basal part of the Petrel Peak Member as suggested by a well-developed desiccation surface at Concretion Point.

Comparisons with other areas

The general stratigraphical and facial development of the sedimentary sequence at Kirwanveggen agree well with the sequence previously studied at Heimefrontfjella (Larsson et al. 1990). Thus, in both areas a glacial stage with tillite formation is followed by a melt-out phase with deposition of fine-grained sediments and a third phase with deposition of fluviatile coarse sandstones. In detail there are considerable differences reflecting the local topographical conditions and supply of material. One striking difference is the absence of dropstones at Kirwanveggen. This can probably be explained by conditions with much shallower water streams which did not permit transport of debris-filled ice floes. In Heimefrontfjella, the general stream conditions have been deeper which is shown by the sediments and sedimentary structures and by prolific occurrences of dropstones.

At this preliminary stage of the investigation it is obvious that at least the major part of the sedimentary cover at Kirwanveggen can be assumed to be of Permian age. This assumption is supported by the nature of the plant remains which agree with material previously collected in Heimefrontfjella, and also by the general agreement in the lithostratigraphy of the sequence at Heimefrontfjella, which belongs to the lowermost Permian (Larsson et al. 1990). Probably, the uppermost unit, the Petrel Peak Member can be referred to the Permian, but it must be emphasized that, so far, no diagnostic macro-plant remains have been observed which could give some age indication, and the vertebrate remains found do not contribute either to the age determination.

The Urfjell Group

Only two short visits were made to the Urfjell area in order to obtain an overview of the area for planning of future fieldwork. The Urfjell Group (Aucamp et al. 1972) is mainly composed of conglomeratic sandstones and quartzites and the entire sequence is deformed by folding and faulting, making correlation between the various nunataks difficult. Our brief visits resulted in some sampling of various lithologies for reference purposes. Two horizons of marble were found, which hopefully could give some indications of the age of this unit. The formation probably has a terrestrial origin which certainly makes finds of diagnostic fossils difficult.

The Kirwanveggen Formation

This unit, composed mainly of basalt flows, was mainly investigated for palaeomagnetic purposes, which will be described below. However, it was also examined for sedimentological purposes as a number of sedimentary intercalations occur between the basaltic flows. Intercalated sandstones of the same nature have previously been reported from Vestfjella (Larsson 1990, 1991), which show, that the Jurassic magmatism has halted periodically permitting the deposition of clastic material from denuded sedimentary formations in the adjacent areas. In Kirwanveggen, these sedimentary intercalations show a different depositional pattern as sand and silt have been transported over boulder surfaces infiltrating into the voids between these boulders. The clastics show some graded bedding within these filled voids suggesting rhythmic infill of the material. Two horizons with red sand- and siltstones were identified at Turnaround Ridge (Figure 1) one each at Mt. Alex du Toit and at the northern escarpment of Mt. Lund. At all three nunataks, the uppermost sandstone horizons seem to occupy the same stratigraphical level, i.e. immediately below the jointed flow reported by Harris et al. (1990). At Mt. Alex du Toit one sandstone dike was also found in the lowermost basalt flow.

Additional fieldwork in Vestfjella

A few days were also spent at the previously visited localities of Fossilryggen, Plogen and Basen (Figure 4), mainly to obtain reference samples for the palaeomagnetical investigation. Some renewed sampling was also made of the sandstone strata intercalated in the basaltic flows. At Basen, a new sandstone horizon was found at a higher stratigraphical level than sampled before, located at the wind channel north of the

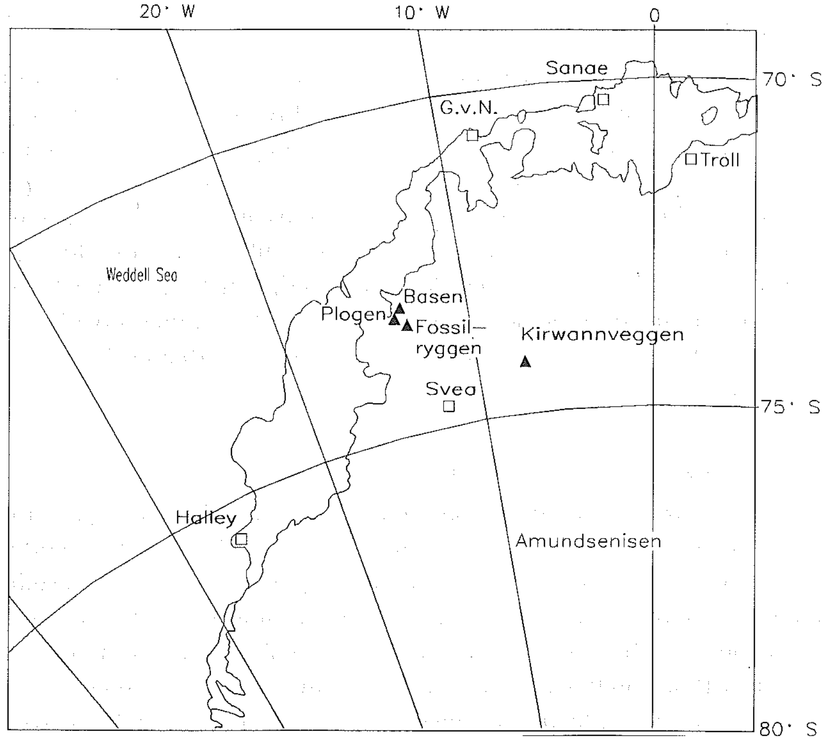

Figure 4. Locations visited (filled triangles) by the geological team during the 1991/92 field season.

Nordenskiöld Base. These sandstones agree well with those observed at Kirwanveggen being red sand- and siltstones filling out voids between the basalt boulders. The superimposed basalt flow cuts down into this clastic horizon indicating a resumed volcanic activity after some halting in the magmatism.

Palaeomagnetism

Orientated rock samples were collected for palaeomagnetic studies from the Jurassic volcanics and the underlying Permian sedimentary cover and the Precambrian basement. This was made in order (a) to determine the orientation and position of western Dronning Maud Land in Gondwanaland and during the break-up of this supercontinent; (b) to improve the apparent polar wander path for Antarctica; and (c) to detect possible tectonic movements between different parts of western Antarctica by comparison with palaeomagnetic data from elsewhere.

The sampling was made in the southern part of the Kirwanveggen area with a concentration to Mt. Alex du Toit and surrounding nunataks. Mainly lavaflows were sampled and a full succession was collected on Mt. Alex du Toit. Minor feeder dykes and sills were found and sampled on the nunataks Petrel Peak and Frostbite Bluff. One lava flow was sampled on Sembberget situated halfway between Kirwanveggen and Heimefrontfjella. Samples of Permian sandstones and siltstones were obtained on Mt. Alex du Toit, Petrel Peak, Frostbite Bluff and Concretion Point. Basement gneisses were collected on the same nunataks. Samples for baked contact tests were taken from the uppermost strata of the Permian sediments on Mt. Alex du Toit. Only hand samples were collected and the orientation was determined by magnetic compass and sun compass. The magnetic variation was found to be -16° which is in agreement with GPS-determinations for the area. In total, 232 samples were obtained from the Jurassic lavas and 57 from the sediments and the basement.

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