ABSTRACT. Outcrops and cores of the Sirius Group sediments were studied at Table Mountain, Dry Valleys area, Antarctica. These sediments form a surficial veneer at least 9.5 m thick. Three facies – a gravelly sandstone, a sandstone, and a sandy conglomerate – are mapped and described from 13 outcrops and three cores. The gravelly sandstone, constituting 13% of all cored material, is bimodal with matrix-supported clasts comprising 5–33% of the facies. Fabric analysis indicates that it was deposited primarily by lodgment from glacial ice but with minor elements of meltout and flow. The sandstone facies, constituting 77% of all cored material, is a well-sorted, fine- to medium-grained sand, which commonly has laminated bedding. It is predominantly a glaciofluvial deposit but has some glaciolacustrine elements. The sandy conglomerate, constituting 10% of all cored material, is a minor facies. It is massive and clast-supported. It was deposited in a high-energy environment suggestive of subglacial meltwater channels.

Sirius Group sediments at Table Mountain are the result of wet-based ice advancing and retreating over waterlain deposits. This is consistent with an advancing ice mass in climatic conditions that were warmer than present. The majority of the sediments were deposited by alpine ice following a similar pathway to the present-day Ferrar Glacier and as such the depositional environment is one that concurs with evidence of a stable East Antarctic Ice Sheet approach. At Table Mountain, the predominantly glaciofluvial and glaciolacustrine facies is inferred to represent a more distal part of the Sirius Group environment than that seen at other outcrops in the Dry Valleys.

Introduction

The Sirius Group is a series of glacigenic sediments that are found mostly at elevations greater than 1600 m in over 40 locations throughout the Transantarctic Mountains (TAM) (Mercer 1972; Mayewski 1975; Barrett and Powell 1982; McKelvey et al. 1991). They have been generally described as a compact glacial drift that unconformably covers pre-Tertiary rocks (Mercer 1972). In the past few years, Sirius Group deposits have been at the centre of a debate concerning the relative stability of the East Antarctic Ice Sheet (EAIS) since the Miocene (Barrett 1997; Miller and Mabin 1998). The debate has largely focussed on the two opposing views of the ‘stabilist’ approach (Marchant et al. 1993; Denton et al. 1993), and the ‘dynamicist’ argument (Webb et al. 1984). Considerable importance has been placed on the presence or lack of Pliocene diatoms in near-surface Sirius Group deposits and their mode of deposition (Barrett et al. 1992; Webb and Harwood 1991; Burkle and Potter 1996; Barrett 1997). If marine diatoms, found in the Sirius Group, are attributed to aeolian deposition and subsequent recycling (e.g. Stroeven and Prentice 1997), they are unlikely to represent the true age of the deposits. Furthermore, both non-marine and marine diatom assemblages found in the Sirius Group may represent numerous palaeoenvironmental conditions.

The age of the Sirius Group deposits on Table Mountain has been estimated by several means. Barrett and Powell (1982) identified three units of glacigenic sediment: diamictite, conglomerate, and sandstone. Based upon regional geology, they suggested these were probably older than late Miocene. Minimum ages of 2.6–2.9 Ma and 6 Ma were established for exposed surfaces at Table Mountain using $^{10}$Be and $^{3}$He/$^{21}$Ne respectively, and it is likely that the deposits are indeed much older (Ivy-Ochs et al. 1995; Bruno et al. 1997).

There are few comprehensive lithostratigraphic studies of Sirius Group deposits in the Dry Valleys area and those that are available relate either to provenance (Faure and Taylor 1981; Taylor and Faure 1983) or to a broad-brush interpretation of glacial geology (Mayewski 1975; Barrett and Powell 1982; McKelvey et al. 1991). They have been generally described as a compact glacial drift that unconformably covers pre-Tertiary rocks (Mercer 1972).
The most comprehensive work on the glacial geology of the Sirius Group was reported by Stroeven and Prentice (1997) who addressed the issue of alpine versus ice sheet glaciation, an issue which is linked to the stabilist–dynamicist debate. Stroeven and Prentice (1997) refute the dynamicist theory that the EAIS was much reduced in area and volume during the Pliocene by producing an alpine ice interpretation for Sirius Group deposits at Mount Fleming. They suggest that the Sirius Group deposits at Mount Fleming were not laid down by expansion of the EAIS, which is assumed to have been relatively stable during warm periods in the Pliocene (Stroeven and Prentice 1997).

At Table Mountain the Sirius Group forms a veneer of sediment, deposited on a gentle slope that formed the bottom of the ancestral Ferrar Valley. Today the Sirius Group at Table Mountain is perched about 1000 m above the present surface of the Ferrar Glacier, at an elevation of 2000 m. In this paper we investigate the depositional environment of the Sirius Group at Table Mountain using surface exposures and cores.
Physical setting
Table Mountain is located on the southern side of the Ferrar Glacier and is bounded to the southwest by the Tedrow Glacier, and to the east by the Emmanuel Glacier (Fig. 1A). Basement rock at Table Mountain is early Palaeozoic granite which is unconformably overlain by Devonian sediments of the Beacon Supergroup comprising the continental sequence of Windy Gully Sandstone, Terra Cotta Siltstone, and New Mountain Sandstone (Fig. 1B).
This sequence of sandstone and siltstone was subsequently intruded by the Ferrar Dolerite in the Jurassic (Barrett and Powell 1982; Fig. 1B).

The study area is a broad, gently dipping slope between 1750 and 2000 m elevation, on the northwest side of Table Mountain. It is about 750 m above the present-day Ferrar Glacier, and is covered by a residual regolith comprising predominantly dolerite clasts, ranging in size from granules to large boulders derived from Sirius Group deposits. Sirius Group deposits at Table Mountain generally crop out as either low ridges covered by residual regolith,
Table 1b. Summary interpretation of fabric data.

<table>
<thead>
<tr>
<th>Site</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>Predominantly lodgment tillite – deposited from SW (Tedrow direction), reworked by ice from W (Ferrar direction)</td>
</tr>
<tr>
<td>TM-1</td>
<td>Three distinct units of predominantly lodgment tillite separated by sand-filled shear planes (units b &amp; d) – shows reorientation of flow from SW to W</td>
</tr>
<tr>
<td>TM-1c</td>
<td>Predominantly lodgment superposed on flow (shear cluster) – deposited from W, although initial deposition probably from SW</td>
</tr>
<tr>
<td>TM-1e</td>
<td>Probably lodgment from W reoriented by more lodgment from SW direction. Some clast rolling during deposition</td>
</tr>
<tr>
<td>J2</td>
<td>Predominantly flow tillite, iceberg-rafted material related to ice movement from W. Some ice marginal reworking – possible remnant bimodal lodgment fabric</td>
</tr>
<tr>
<td>J3</td>
<td>Strong lodgment of boulder into underlying lodgment tillite – reorientation of clasts indicate ice from W overridden material emplaced by weaker lodgment from SW</td>
</tr>
<tr>
<td>TM-6</td>
<td>Transition from lodgment to flow tillite – ice advance with subsequent stalling/ice marginal reworking. Overridden ice marginal lake sediments at base</td>
</tr>
<tr>
<td>TM-6a</td>
<td>Lodgment from W superposed on lodgment from SW – both shears and tension fractures present</td>
</tr>
<tr>
<td>TM-6b</td>
<td>Strong lodgment from W with some spread perhaps by subglacial meltout</td>
</tr>
<tr>
<td>TM-6c</td>
<td>Predominantly meltout – palaeodirection from W – possibly some earlier lodgment (weak transverse mode)</td>
</tr>
<tr>
<td>TM-6d</td>
<td>Flow till, reworking post-depositionally, no striae. Flow from till ridge?</td>
</tr>
<tr>
<td>TM-7</td>
<td>Bottom section represents lake/ponded sediments separated by an erosional contact from overlying conglomerates – Overriding ice sheared conglomerate into overlying tillite – overloading and dewatering structures present</td>
</tr>
<tr>
<td>TM-7a</td>
<td>Predominantly lodgment with some meltout (spreadout unimodal fabric, but not a girdle generated by flows) – some clasts rotated in viscous flow at base</td>
</tr>
<tr>
<td>TM-7b</td>
<td>Strong lodgment – associated flow in underlying sediments</td>
</tr>
<tr>
<td>J6</td>
<td>Strong lodgment by ice moving from W. Appears to have lodged into proglacial deposits of waterlain sediment. Brecciated sands and water escape features</td>
</tr>
<tr>
<td>6.34</td>
<td>Strong lodgment of ice moving from W. Has lodged/sheared up at the top of the main ridge adjacent to hollow. Might mark confluence with cleaner ice to east. Some clasts have rolled/slid and some vertical rotation which might be due to overtopping of a moraine ridge/settling. Strong shear indicates active lodgment from west.</td>
</tr>
<tr>
<td>11.1</td>
<td>This section represents a weak stagnating SW ice flow (much meltwater) overridden by active ice from W</td>
</tr>
<tr>
<td>11.1a</td>
<td>Probable meltout, ice from SW – possibly waning in comparison to ice from W? Very weak transverse mode suggests possible lodgment involved in lower part of unit</td>
</tr>
<tr>
<td>11.1b</td>
<td>Strong lodgment from W – some settling indicated by reverse modality, perhaps caused by underlying instability in meltout?</td>
</tr>
<tr>
<td>12.17</td>
<td>Strong lodgment of ice moving from W. Lodgment into a moraine-dammed lake, the oversteepened tillite has settled slightly, some subsequent meltout has occurred</td>
</tr>
<tr>
<td>J11</td>
<td>Weak meltout of a thin veneer of subglacial material. Striae data are equivocal – ice from S., bimodal fabric from some rolling/sliding suggests general SSW movement</td>
</tr>
<tr>
<td>J12</td>
<td>Weak meltout of a thin veneer of subglacial material. Unconsolidated material, fabric generally strong but deflation and settling appears to have generated bimodality</td>
</tr>
</tbody>
</table>

Refer to Fig. 1 for site locations. Refer to Table 1a and Fig. 4 for fabric data. Units a, b, c, d, e were measured from the base of the section upwards, a = lowest unit in a section and so on.

Methods

Field mapping was carried out by ‘pace and compass’ with elevations determined using a combination of a THOMMEN surveying altimeter, and GPS sites which were fixed to the trigonometrical station at Table Mountain. A magnetic correction of 154° was used to give true grid readings. Fabric was recorded at 12 outcrops by measuring the trend and plunge of the long axis of about 50 prolate clasts in each subsample. Data were plotted on Schmidt equal-area projections, and additional

or beneath mounds of large boulders of residual regolith. One outcrop is a prominent ridge that forms the highest elevation of the Sirius Group at Table Mountain. This ridge is adjacent to a prominent elongated depression that strikes northeast and contains outcrops of the Terra Cotta Siltstone. A series of less well defined, subparallel NE-trending ridges is found downslope from this main ridge (Fig. 1B). Patterned ground and several large mass movement features indicate some degree of post-depositional reworking in some areas.
Fig. 4. Fabric data for all major outcrops studied—see Fig. 1 for site locations. Stereonets include clast imbrication, striae (top surface striae: black fill rose diagram, bottom surface striae: grey fill rose diagram), poles to shear planes (black fill squares), and stoss/lee features (black fill circles indicate orientation of stoss end, adjacent number = number of clasts with this orientation); see Table 1 for a summary of data, directional and depositional interpretations. These are lower hemisphere plots of a Lambert/Schmidt equal-area projection. Dip and dip direction are contoured at 2% intervals.
data such as striae, stoss/lee features and keels were noted and used to assist with interpretation. Percentage gravel, and the ratio of sand to mud were plotted to determine primary textural names.

Cores were taken with a portable drilling system using compressed air as a flushing medium (Dickinson et al. 1999). Cores were stored frozen at a constant temperature of –18°C and grain size samples were taken at approximately 0.5 m intervals from three cores (TM-1C, TM-6, TM-7B). Sample weight was generally about 20 g but the true clast content of the conglomerate was not well represented. To address this problem, the percentage gravel measured from grain size analysis was replaced by a visual estimate of clast content of the conglomerate units. For analysis of the conglomerate, percentage sand, silt, and mud have been normalized to the estimated gravel percentage.

**Results and discussion**

**Outcrops**

Three distinct lithological facies were mapped and described from 13 outcrops at Table Mountain (Figs 1B, 2–4). These facies are a gravelly sandstone, sandstone, and sandy conglomerate. To avoid possible misinterpretations associated with names such as tillite and diamicl, all lithological descriptions in this text follow the textural classification of Folk et al. (1970).
Gravelly sandstone facies. In surface exposures, this is the most extensive and variable of the three facies (Fig. 2a). Typically it is a massive, light pinkish brown to light brownish grey, bimodal, gravelly sandstone. The mainly subangular clasts constitute 5–33% of the material and range in size from granules to cobbles. Clast lithology is predominantly dolerite, with some siltstone, quartz arenite, and quartz. This facies is commonly cut by northwest-dipping fractures imparted during deposition, some of which are intruded by veins of sandstone (see below). In addition, there are numerous shear, deformation, water-escape structures and lenses of both sandstone and conglomerate. There is considerable variation in clast lithology and stratification, but because the clasts are mostly striated and strongly oriented in the direction of palaeoflow, this facies has been interpreted as a subglacial diamicton. This interpretation is refined using fabric analysis (Table 1, Fig. 4).

The base of the gravelly sandstone facies was visible at two sites, 11.1 and TM-7. At site 11.1, the facies overlies Terra Cotta Siltstone with a sharp and undulated lower contact (Fig. 2a). The base comprises a clast-rich (30–60%) sandy conglomerate. The predominantly clasts are angular and range in size from granules to large cobbles. Shale concentrations decrease upsection and the unit grades into a typical gravelly sandstone with large dolerite boulders (<1.5 m a-axis).

At TM-7, a sharp erosional contact overlies the sandstone facies of the Sirius Group and clasts have a strong preferred orientation to the west-northwest with parallel striae and stoss/lee features. The fabric is strong, and while lodgment is the predominant process involved, there are elements of melt-out, and possibly flow as indicated by a relatively dispersed fabric (at site TM-7d). The overall picture is of an initial strong lodgment of material by active ice flowing from the west-northwest, followed by subsequent stagnation and decay. It is possible that overriding by a more recent ice advance, or periglacial or mass wasting processes could have imparted a dispersed fabric. However, these alternative scenarios are unlikely because of the lack of evidence for a subsequent ice advance. Furthermore, the ubiquitous nature of the fabric at these sites indicates that locally variable periglacial or mass wasting processes have not substantially altered the (macro)fabric.

While fabric for sites TM-1 and 1.0 further east have a slightly weaker cluster of points, they are lodgment in origin. They also indicate deposition from active ice which flowed from the west-northwest.

In contrast, fabric data from outcrops at sites 11.1 and J3, indicate that there was a change in ice flow direction. These data indicate weak lodgment by ice flow from the southwest with subsequent overriding by strong lodgment by ice flow from the west. This has been interpreted as representing the overriding of waning Tedrow Glacier ice by the rapidly advancing Ferrar Glacier ice. Ice from the Tedrow Glacier direction is inferred to have reached a maximum ice front towards the southwest corner of the study site where it merged with Ferrar Glacier ice.

Other sites confirm this strong lodgment signal of ice advancing from the west. Site 6.34 is located on the uppermost moraine ridge (Fig. 1B) and shows evidence of active till emplacement with lodgment of material. Some vertical clast rotation has been caused by moraine overtopping and subsequent settling out of material. Further downslope, sites J6 (west) and 12.17 (north) represent active ice advances into waterlain sediments and water, respectively. Water-escape features and brecciated sands were recorded at J6, and the post-depositional settling of lodgment till was found at 12.17. Emplacement by active ice in these two downslope locations is also shown by the occurrence of granitic clasts sourced from below the dolerite sill. These have been sheared up over the sill, but have not been carried to the uppermost moraine ridges.

Gravelly sandstone deposits at sites J11 and J12 are anomalous. They do not indicate the almost ubiquitous deposition associated with active Ferrar Ice flow. The fabric indicates the presence of a locally derived ice mass flowing from the Table Mountain–Navajo Butte area to the south-southwest. These deposits are thin, unconsolidated, and run subparallel to the elongate depression (hollow) adjacent to the uppermost moraine ridge.

Sandstone facies. This facies was rare in outcrop but was generally found in topographic depressions beneath a veneer of surface debris; however, it was abundant in all cores (Fig. 2b). The sandstone facies is also rare or non-existent in other Sirius Group outcrops in the Dry Valleys area, probably reflecting the absence of core data. Texturally, the sandstone is the most homogeneous and friable of the three facies. Typically, it is a light brown, well sorted, medium to fine sandstone that contains few gravel-sized clasts (<2%). Outcrops and cores of
the facies show fine laminations, and contain rare dispersed dropstone clasts.

At site 6.34 the facies was found in outcrop and contained two distinct units. The lower unit had fine (<5 mm), planar stratification while the upper unit was massive, and contained clasts with associated soft sediment deformation. Horizontal stratification and the presence of dropstones indicate that these sediments were deposited in a proglacial environment often involving ice-rafted debris. To the west, at site TM-7, the sandstone facies is overlain by gravelly sandstone, indicating that an advancing glacier overrode proglacial sediments.

The morphological expression of the Sirius Group sediments in the study area indicates that most of the ridges are end-moraines composed of gravelly sandstone facies and the sandstone facies is located in hollows between the ridges. The sandstone facies is interpreted as being a predominantly glaciofluvial deposit with some glaciolacustrine elements. The sandstone would most likely have been deposited in streams feeding moraine-dammed lakes that formed in a distal environment as the glacier retreated. Such relatively coarse-grained lake sediments are unusual, but may indicate the high energy regime associated with a predominantly glaciofluvial environment.

Sandy conglomerate facies. The least extensive of the three facies is mainly found in flat areas clear of surface debris (Fig. 2c). It is typically a light pinkish grey, massive, bimodal, sandy conglomerate (e.g. site 6.28). The matrix is a well sorted, medium sand. Clast-supported material (50–80% clasts) is mostly well rounded, granule to cobble-sized, and poorly sorted. Clast lithologies are mainly dolerite, with some quartz and quartz arenite.

This facies is generally associated with the gravelly sandstone. However, unlike the gravelly sandstone it is clast-supported. The rounded clasts and coarse texture indicate that this was deposited in a high-energy environment. The form of the association of the sandy conglomerate with the gravelly sandstone at sites 11.1 and TM-6 indicates that the sandy conglomerate was deposited in subglacial meltwater channels and deposition must have been rapid because striae are preserved on several clasts. However, where it is exposed in depressions and in association with the sandstone facies, it appears to have been laid down either as a result of slumping or channel fill.

Cores

TM-1C. A 7.9 m core was taken from a small outcrop of gravelly sandstone located at the southern end of the highest ridge (1948 m a.s.l.). The core was subdivided into seven units and contained examples of all three facies (Fig. 5).

Sandstone is the dominant facies in the lower half of TM-1C, with the lowest unit being highly deformed by both subhorizontal and vertical fractures. Bedding within the sandstone includes planar low-angle, planar high-angle, and trough cross-bedding. The facies has two erosional contacts, both of which are overlain by fining-upward sequences, the former from a gravelly sandstone to a fine sandstone, the latter from a sandy conglomerate to a coarse sandstone.

TM-6. This 4.1 m core was taken at an elevation of 1909 m a.s.l. on a low ridge, subparallel to the dip of the slope. The core contains four units of gravelly sandstone and a sharp, erosional contact between units 2 and 3 that is considered to be a shear plane. The lower contact with the underlying Beacon Supergroup was not cored, but clasts in the lowest unit are dominated by the grey Terra Cotta Siltstone, indicating that it may represent the top of a basal unit, similar to that seen at site 11.1.

Grain size analysis shows that all units are bimodal, with an additional bimodality in the sand range that is most likely conferred by incorporation of a combination of the Windy Gully and New Mountain Sandstones.

TM-7B. A 9.5 m core (elevation: 1863 m a.s.l.) was taken at a gravelly sandstone outcrop on a long, eastward-trending ridge. Most of the 11 units found in this core were sandstone facies. The gravelly sandstone facies on the surface was not recovered in the drill core, but was assumed to have extended about 0.4 m below the surface. Grain size data show that most units range from well sorted to poorly sorted. Coal clasts (<1%) are uniformly distributed throughout the sandstone facies, and in places they form discrete lenses up to 10 mm thick.

Core summary

The gravelly sandstone facies comprises 13% of all cored material recovered, as opposed to 10% for the sandy conglomerate, and 77% for the widespread sandstone facies.

A comparison of the facies from the cores and outcrops shows that the gravelly sandstone found in...
Fig. 6. Schematic model of the depositional sequence on Table Mountain from emplacement of the uppermost moraine (it is assumed that bedrock underlies these deposits. Bedrock forms the base of the hollow). (A) Active lodgment of material, some overspill from the uppermost moraine into the abutting bedrock-lined hollow (possibly ice-filled), granite sheared up from beneath dolerite sill, reworking and overloading of ice marginal sediments. (B) Ice retreat/downwasting, aeolian and meltwater processes active, melting of any ice in bedrock-lined hollow. (C) Continued ice retreat/downwasting, aeolian removal of material from bedrock-lined hollow, slumping and settling of oversteepened moraine ridges, continued meltwater processes. (D) Ice downwasted, ongoing periglacial processes (aeolian, mass movement and meltwater), most material transported below dolerite sill is removed by new Ferrar Glacier ice carving a deeper valley west of Table Mountain.
the upper parts of cores TM-1C and TM-6, is the same as that studied in outcrop. Furthermore, there is little variation in the gravelly sandstone with depth. However, the proportion of sandstone to gravelly sandstone is much greater in the cores than in outcrop with the sandstone sequences at least 9 m thick at one site. Stratigraphically, the sandstone is the lowest facies of the Sirius Group (Fig. 5).

In the cores, the sandstone facies ranges from massive to cross-bedded, and contains erosional contacts overlain by fining-upward sequences. Pebble lenses are also common in many of the units. These features suggest that at least some of the sandstone was deposited in a high energy environment comparable with hypothetical fluvial models presented by Miall (1978). Although the sandstone in the cores more closely resembles the Platte-type model, features of both the Donjek- and Platte-types are seen (Miall 1978). However, the presence of ice-rafted dropstones throughout the sandstone in the core shows that these sediments were deposited in an ice marginal zone with a combination of glaciolacustrine and glaciofluvial environments.

Core TM-1C has a sequence of sandstone overlain by gravelly sandstone, which is believed to represent glacial overriding of a glaciofluvial environment, in other words, an ice advance. Although this sequence suggests one glacial advance, there is evidence in the core to suggest there may have been several advances. The lowest part of the sandstone facies is highly deformed and has an upper erosional contact with the sandy conglomerate facies. This contact might represent an earlier glacial advance across, and deforming, the proglacial sediments.

Core TM-6 was drilled through an outcrop of the gravelly sandstone facies at least 4.0 m thick. The sequence was deposited by a glacier advancing over glaciofluvial or glaciolacustrine sediments, similar to the interpretation for core TM-1C. As the sandstone is not seen in the bottom of core TM-6, this might indicate that either the fluvial sediments were completely removed by advancing ice or that core TM-6 was drilled to the side of a fluvial channel.

The sediments described in core TM-7B are predominantly sandstone that has been overlain by gravelly sandstone interpreted to be basal till. This is the same sequence as found in core TM-1C and is also interpreted as a glacial advance. However, since core TM-7B does not extend into the underlying rocks of the Beacon Supergroup, no earlier possible advances can be determined.

Provenance

Provenance of the Sirius Group at Table Mountain can be estimated from the proportion of different clast types seen in outcrop (Table 1). About 67% of all clasts in the Sirius Group are dolerite. Clasts constitute approximately 21% of the total outcrop, and therefore, as much as 15% of the Sirius Group at Table Mountain has probably been derived from Ferrar Dolerite, which forms sills and dykes throughout the TAM. About 85% of outcrop material includes siltstone gravels, quartz arenite gravels, sand, silt and mud that is most likely from the Beacon Supergroup. The gravels rich in quartz clasts (about 1% of the total outcrop), are thought to have come from the Feather Conglomerate. This formation of the Beacon Supergroup crops out at Mount Feather, 35 km to the east, and up-glacier from Table Mountain (McElroy and Rose 1987).

A similar exercise can be carried out for the cores. From the average proportion of gravel-sized clasts estimated for each core it is also possible to evaluate the provenance of the material of the Sirius Group at Table Mountain. The estimated clast contents are: TM-1C 15%, TM-6 14%, TM-7B 3%. The proportion of dolerite, quartz arenite, and mudstone clasts is approximately the same as in the outcrops which means that about 7% of the Sirius Group at Table Mountain is from the Ferrar Dolerite, and 93% is from the Beacon Supergroup. The small amounts (<1%) of coal found throughout the sandstone facies of the cores is most likely from the Weller Coal Measures, a formation within the Victoria Group, which forms the upper part of the Beacon Supergroup. The Weller Coal Measures crop out at the tops of Mount Feather and Mount Weller (McElroy and Rose 1987) which are about 35 km to the east, and up-glacier of Table Mountain.

Depositional model

In this paper the Sirius Group at Table Mountain is described in terms of three distinct lithofacies. Sandstone is the most common facies in core (77% of core), but not in outcrop, and is stratigraphically the lowest part of the Sirius Group. The sandstone facies is rare at all other Sirius Group sites in the Dry Valleys area. While this may be a function of the absence of coring at other locations, it may also represent the erosional expression of the deposits at Table Mountain. Our data show that the environment of deposition for the sandstone facies is thought to be both glaciofluvial and glaciolacustrine. Gravelly sandstone is the next most common facies in core
and is interpreted as till or diamicton. This forms a thin layer above the sandstone facies, and accounts for most of the outcrops seen at Table Mountain. The third facies is a sandy conglomerate, which is relatively sparse in both outcrop and core and is found largely as lenses in the sandstone facies. Deposition is believed to have taken place mainly in subglacial meltwater channels. Aspects of the topography at Table Mountain have a strong relationship to the distribution of the different facies. Facies appear to control the present morphological expression. Ridges are capped by gravelly sandstone overlying the sandstone facies which is mainly exposed in the intervening depressions or beneath large boulders. The presence of mass movement features and patterned ground indicates some degree of post-depositional reworking, but this does not appear to have affected the macrofabric of prolate clasts. The effect of patterned ground processes upon microfabric, and lateral and vertical movement within the sediments was not determined.

The presence of coal and quartz clasts in the Sirius Group indicate an easterly flow bringing erratics from about 35 km to the east near Mount Feather. However, the form of the channel in which the glaciofluvial sediments were deposited may have been very different from the present Ferrar valley. Barrett and Powell (1982) proposed that a broad, relatively shallow valley existed between Table Mountain and Knobhead (Fig. 1A). While there is no direct evidence in the cores to support this model, the valley floor on which the glaciofluvial sediments were deposited must have been at an elevation similar to the base of these sediments. Therefore, the valley would have been similar to the profile indicated by Barrett and Powell (1982).

We propose a model of the depositional sequence which starts from the emplacement of the uppermost moraine ridge (Fig. 6). For simplicity, the model only considers depositional and post-depositional events with respect to a retreat and downwasting from this point. Alpine ice advanced over glaciofluvial material and then as it retreated a series of end moraines formed with meltwater drainage through inter-moraine streams and lakes. Final ice retreat left a topography of glaciofluvial sediments overlain by a thin veneer of subglacial diamictons. Contemporary and subsequent aeolian processes have created a residual regolith which serves to armour the underlying sediments. Localised mass movement and patterned ground processes have also contributed to the present geomorphology.

Many of the sedimentary structures and grain size analyses show deposition by glaciofluvial and glaciolacustrine conditions indicating wetter conditions than exist today. The proposed depositional model suggests a rapid ice advance (e.g. Menzies 1995), although we are unable to assess the rapidity from the data available.

Climatic conditions were warmer than present and the deposits at Table Mountain appear to represent the maximum extent of a Ferrar Glacier ice advance, although subsequent erosion has removed some of the evidence. It is probable that the advance represented a change from cold to wet-based ice. Clast provenance and the interaction between small ice masses (Tedrow Glacier ice, Table Mountain-Navajo Butte ice, and Ferrar Glacier ice) are interpreted as representing deposition by alpine ice as opposed to an ice sheet advance. This work supports that of Stroeven and Prentice (1997) at Mount Fleming in favouring a stable ice sheet scenario.

The Sirius Group deposits on Table Mountain are a small part of the entire group (McKelvey et al. 1991) and further glacial geological work is needed to see if they are representative of depositional environments at other sites. However, the presence of small pockets of Sirius Group deposits at other locations is inferred to represent similar small alpine ice advances in response to a warming climate. At Table Mountain, the predominantly glaciofluvial and glaciolacustrine facies is inferred to represent a more distal part of the Sirius Group environment than that seen at other outcrops in the Dry Valleys.

Conclusions

Sirius Group deposits at Table Mountain are believed to be the result of wet-based ice advancing and retreating over waterlain material. The topography is largely deglacial, and has in localised areas been modified by periglacial processes and mass movement, which seems to have had little effect upon the macrofabric of outcrop and cores. The maximum extent of Ferrar ice advance at this site is marked by the uppermost moraine ridge that abuts a bedrock-floored elongate depression. Subsequent ice retreat and downwasting from this point is marked by a series of subparallel ridges with meltwater (glaciofluvial and glaciolacustrine) deposits laid down between them.

When Ferrar ice advanced from the west, the southwestern part of Table Mountain appears to have been occupied by a weaker ice mass emanating from the direction of the Tedrow Glacier. This
DEPOSITIONAL ENVIRONMENT OF SIRIUS GROUP SEDIMENTS

is indicated by variations in fabric and composition. This ice mass was subsequently overridden and much of its glaciogenic sediments were re-worked. At the time of maximum advance it is possible that the uppermost bedrock-floored hollow was filled with ice flowing from the Table Mountain–Navajo Butte area. However, there is no direct evidence for the occupation of the hollow by ice from any source.

Most subglacial diamicton was emplaced by lodgment, and on the lower slopes of the study area there is evidence for active ice introducing granitic material from beneath the dolerite sill. Active shearing was also evident from within the outcrops and cores studied where lodgment overlies glaciofluvial material. Deposition is consistent with advancing ice, although the rapidity of the advance cannot be determined from the available data. The interactions between three alpine ice sources indicate that these sediments were not laid down by expansion of the EAIS and this supports the stabilist conclusions of Stroeven and Prentice (1997).

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Dr James R. Goff, GeoEnvironmental Consultants, 11 The Terrace, Governors Bay, Lyttelton RD1, New Zealand
E-mail: geoenv@xtra.co.nz

Ian W. Jennings, Research School of Earth Sciences, Victoria University of Wellington, PO Box 600, Wellington, New Zealand

Dr Warren W. Dickinson, Research School of Earth Sciences, Victoria University of Wellington, PO Box 600, Wellington, New Zealand
E-mail: warren.dickinson@vuw.ac.nz

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