Geology of the southeastern Eyre Mountains relevant to tenure review

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Abstract

Several properties within the eastern Eyre Mountains are currently undergoing tenure revue. This report provides geological information relevant to these reviews, particularly on the sequence of glacial deposits south from Kingston.

The geology of the Eyre Mountains is dominated by low-grade metasedimentary rocks of the Permian Caples terrane, becoming increasingly schistose toward the northeast. Volcanic rocks and serpentinite occur in the southwest of the area. The semischists are folded into a large synform, producing flat-lying ledges and steep bluffs, also controlled by vertical joints. The Eyre Mountains semischists are cut by several major faults; only the Moonlight Fault shows evidence of Recent activity. The region has been heavily glaciated, leaving deep U-shaped valleys in the central mountains and wide valleys infilled with moraine and outwash deposits to the northwest (Von - Oreti - Mararoa catchments) and southeast (Mataura catchment). These valley deposits allow major glacial advance ice limits to be inferred for the region, up to c. 500 000 years BP in age. Within the Eyre Mountains, deposits are limited to cirque moraines, valley floor alluvium, fans, and extensive screes. Landslides are developed on slopes underlain by dipping schistosity, especially in the eastern Eyre Mountains.

Within the region, there are no known mineral, geological or structural features that are unique or of regional significance. However, the glacial landforms of the Mataura and Von - Oreti - Mararoa catchments are extremely well preserved, highly visible, of easy access, and of regional to national significance. Developments such as roading, forestry, or building will have negative impacts on these landscapes.

1. Introduction

This report has been prepared at the request of E. Edwards and S. McQueen, DOC Invercargill and DOC Dunedin, and presents information relevant to the following requirements (as per DOC order for external unprogrammed science advice, April 1999):

1, a very brief description of the geology of the Eyre Mountains near Kingston spanning Mataura Valley to Lochy catchment) within the context of the region;

2. a geology map at 1:50 000 scale;

3. significant inherent values for any noteworthy site (e.g. Geopreservation site) and comment on the sensitivity of the site value to land use impacts (e.g. quarrying or production forestry);

4. geological events which may relate to the distribution of plants and animals (e.g. ice retreat events);

5. an interpretation of the Kingston Outwash Channels in terms of Pleistocene and Holocene events and processes.

This report is based on geological data and interpretations summarised in a geological map at a scale of 1:250 000 due to be published in 2000 (Turnbull in prep.). That map in turn is based on published 1:50 000 scale mapping of the northwestern Eyre Mountains (Turnbull 1980), on field mapping undertaken in 1995-97 by the Institute of Geological Nuclear Sciences (GNS) for the 1:250 000 geological map revision, and on the author's familiarity with the region. The 1:250 000 scale map has been simplified from 1:50 000 scale data record maps, held and available for consultation in the Dunedin office of GNS. No new field work was undertaken for this report, which has been reviewed by P.J. Forsyth, P.J. Glassey and D.J.A. Barrell, GNS Dunedin. In addition to this report, a presentation on the geology of the Eyre Mountains region was made to a meeting of DOC staff in Dunedin on 20 March 1999. A preliminary interpretation and discussion of the Kingston area has already been provided to DOC (Turnbull 1995; Appendix 3). Data and conclusions in Appendices 3 and 4 have to some extent been superseded by this report. A 1:50 000 geological map of the southeastern Eyre Mountains is available on request from GNS.

1.2 DATA OWNERSHIP

The geological map included in this report as Fig. 2 presents unpublished data and is subject to GNS copyright. An unpublished GNS Immediate Report on the Quaternary geology of the Kingston - Mataura area (Thomson 1995) forms Appendix 4 of this report and provides additional background information; that Immediate Report is proprietary to GNS and does not form part of the main report. All other information is an integral part of the text and is subject to DOC copyright.

2. Overview of geology

The Eyre Mountains form a distinctive topographic block southwest of lake Wakatipu, rising to 2000 m at Jane Peak (Fig. 1). The area is mountainous and rugged, bush-clad in the southwest but tussock-covered elsewhere, with rocky bluffs and fell fields at higher altitudes. Geologically the Eyre Mountains are underlain by greywacke and semischist of the Caples terrane of Permian age, and are separated from other Caples rocks of northern Southland by the major valley systems of the Mataura and Von-Oyeti catchments which are infilled by extensive glacial and fluvioglacial deposits of Quaternary age (Fig. 2). In the southwest of the range, serpentinite and volcanic rocks of Permian age underlie West Dome and the lower Windley and Acton streams; these are not further discussed in this report. The Eyre Mountains block is cut by several faults, the most significant being the South Von Fault (Turnbull 1980). The regionally significant and much larger Moonlight Fault follows the Von - Oreti valley, where it is almost entirely concealed by glacial gravels. The Eyre Mountains have been heavily glaciated, and glacial erosional features dominate most of the modern landscape. The inferred down-valley limits of the major advances of the Wakatipu glacier are summarised in Fig. 3.

2.1 GREYWACKE

Massive, dark grey to greenish grey sandstone ("greywacke") forms most of the western Eyre Mountains, around Helen Peaks and into the Irthing and Cromel streams and toward Eyre Creek and the South Von (Fig. 2). These rocks are hard, resistant to erosion, and contain only minor amounts of softer and finer-grained mudstone. Fracturing within the greywackes is largely controlled by jointing (i.e. parallel, planar fractures or cracks in the rock, spaced from a few cm to 0.5 m apart) and these rocks tend to break down to form coarse blocky scree slopes.

Lenses of volcanic rock accompanied by thin bands of red mudstone or hard pink or black chert have been mapped along the western side of Eyre Creek and in the Jane Peak massif (Fig. 2). The bands along Eyre Creek lie within a zone of "melange" or mixed-up rock, which includes conglomerate and very rare limestone. At Mid Dome this limestone includes microfossils (conodonts) which are of Permian age (270-285 Ma (million years ago); Ford et al. 1999).

The Caples greywackes were deposited on submarine fans in an oceanic trench setting in Permian to possibly Triassic time (290-180 Ma). The rocks have a volcanic parentage - they are formed of sand eroded from a volcanic hinterland - and tend to have a lower silica content (average 53%) and higher iron and manganese content than similar greywackes of the Canterbury ranges (Roser et al. 1993).

2.2 SEMISCHIST

With increasing metamorphism (heat and pressure), greywacke is converted to semischist and then schist. This metamorphism is dated (radiometrically) as late Jurassic (200 Ma), with uplift and cooling of the rocks lasting into Cretaceous time (100 Ma) (Mortimer 1993). The Eyre Mountains rocks show a very well-developed transition from greywacke into semischist. The transition is mapped (Fig. 2) in terms of textural zones, which reflect increasing development of schistosity (the slabbiness or "splittability" of metamorphic rocks), as well as coarser grain size of metamorphic mica minerals, increasing amounts of quartz veining, and folding of original bedding in the parent sandstones (Photo 1).

Placing boundaries ("isotects") between the various textural grades of schist is subjective, and the isotects should not be regarded as contacts easily seen on the ground - they reflect points in a continuum of changing metamorphic grade. The textural grade is imposed on pre-existing sedimentary textures, and where the parent rock is mudstone (as in the head of the Lochy, and especially in Slate Basin), the semischist is very easily split and eroded. Where the parent is sandstone, for example around Symmetry Peaks, the semischist forms slabby but resistant outcrops.

Minor lithologies within the Eyre Mountains semischist are mostly restricted to a zone of deformed (flattened) conglomerate running from Eyre Creek into the head of the Lochy (Photo 2). Deformed conglomerate is also mapped along the Lake Wakatipu shoreline and in the head of Allen Creek. A thin band of metamorphosed volcanic rocks occurs in a gully north of Mataura Saddle at the head of the Lochy, and other metavolcanic ("greenschist") bands occur along the shore of Lake Wakatipu. These metavolcanic bands are a distinctive greenish colour, due to the abundance of chlorite and epidote minerals. Around Jane Peak, cherts associated with greenschists are managanese-rich and contain rare examples of the semi-precious pink minerals rhodonite and rhodochrosite (Turnbull 1980).

Schistosity in the Eyre Mountains is folded into a major synform (downfold), named the Taieri-Wakatipu Synform (Mortimer & Johnston 1990), which runs from Walter Peak into the upper Mataura Valley. A secondary warp or upfold has been mapped through Cecil Peak from the lower Long Burn, and another minor downfold runs beneath Bayonet Peaks. The effect of this folding is to produce flat-lying semischist in the axis of the fold; the landscape reflects this with flat ledges, steep bluffs (controlled by sub-vertical fracturing or jointing), and "mesa-like" ridge crests and minor summits. Symmetry Peaks are a good example of this, as is Walter Peak (Photo 3). Isolated "gendarmes" or pillars and detached bluffs are joint- and schistosity-controlled landscape features.

Geochemically, the Eyre Mountains semischists are very similar to the parent greywackes, with relatively low quartz content. There is one locality in the upper Lochy below the ruined Forks Hut, where the parent sediments are almost pure volcanic sandstone, and the semischist derived from them is a pale green colour, unlike the more typical silvery-grey colour of most semischist.

2.3 FAULTS

Mapping of most of the faults within the Eyre Mountains - the Forks Fault, the South Von Fault and the Lochy Fault - is based on offset or juxtaposition of the textural zonations within the schists. The Moonlight Fault, traced from the Afton Burn to the Oreti, is also marked in one place in the map area (Fig. 2) by infaulted limestone of Oligocene age (25 Ma) (Turnbull 1980). The faulting marks a major readjustment of the earth's crust during the late Tertiary, partly influenced by movements on the distant Alpine Fault which was at that time pushing the Fiordland massif into the schist terrain around Lake Wakatipu. Only along the Moonlight Fault is there any evidence of major Recent faulting, although a Recent trace (probably less than 6000 years old) was found in the Acton Valley during recent field work.

Many of the mapped faults and their associated crush zones are only exposed in a few places. Major crush zones are exposed below Mataura Saddle, along the Moonlight Fault above Home Creek, and on the Forks Fault north of the Lochy River. These zones of relatively soft, closely jointed rock tend to weather out and form gullies or screes, but they are not a major element of the landscape.

3. Glacial geology

The Eyre Mountains landscape is dominated by the effects of valley glaciation, with spectacular U-shaped valleys and cirques, and terminal moraines and outwash plains in the bounding Matarua and Von-Oreti catchments. The Lake Wakatipu trough, with its tributary and outlet valleys, records a succession of glaciations which date back at least 500 000 years (Fig. 3). It must be noted, however, that nowhere within the area shown in Fig. 3 is there any absolute age control from radiometric dating, and that the following correlations and discussions are based on ages extrapolated from the adjoining Mararoa -Te Anau and Clutha - Kawarau catchments; an element of mis-correlation is likely. In Appendix 4, Thomson (1995) gives locations of key sites and interpretations of the succession of ice advances in the Kingston - Athol area. Glacial advances and events are here correlated using the International Oxygen Isotope Scale (Imbrie et al. 1984), and the informal local names for advances used by Thomson (Appendix 4) are not adopted.

3.1 MAJOR ICE ADVANCES AND DEPOSITS

Late Otiran glacial advance, oxygen isotope (01) stage Q2, 18 000 - 24 000 years BP

The most recent major glacial event saw Wakatipu ice reach Kingston to form a spectacular terminal moraine (Photo 4). Although an outwash gravel plain formed downstream from the terminal moraine early in this advance, for much of the time the Kingston glacier terminus was static and provided an outlet for meltwater draining from the Wakatipu glacier into the upper Mataura catchment. The glacier front is inferred to have moved relatively little during Late Otiran time, producing a succession of terminal ridges within one major moraine deposit (see (Thomson 1995, Appendix 4). Tributary catchments such as the Von and Lochy had ice in their headwaters only, and drained along the western side of the Wakatipu glacier into the Mataura system. The major abandoned meanders which cut into the older outwash plains south of Kingston (Photo 5) formed at this time, and continued to erode the Otiran outwash as the Wakatipu ice melted. There were two meltwater streams, one east of Kingston and a slightly younger one to the west where the Kingston Flyer now runs.

Later, this situation changed when the Kingston outlets were clammed and the Kawarau River became the major outlet for the Wakatipu system during glacial retreat. The eastern Mataura outlet was blocked by alluvial fan gravels from Lorn Peak; the western outlet was closed off by a small moraine wall (now preserved across the Kingston Flyer track; Photo 4). A major post-glacial lake formed in the Wakatipu basin, with well-developed lake benches eroded into the surrounding slopes at an elevation of c. 350 m a.s.l.- including the terrace on which most of Kingston is built. This lake drained via the Kawarau system, not via the Mataura. Features on the Kingston moraine surface inferred to be forest dimples (Brockie 1973a) may also date from this time.

Submerged moraine topography off the Kingston waterfront, together with drowned trees around the western Wakatipu shoreline near Elfin Bay and flooded storm beaches in Frankton Arm, indicate that Lake Wakatipu has been naturally raised several metres. Thomson (1984) has suggested the cause was a landslide at the Kawarau Falls at Frankton, which dammed the lake some 6000 years ago.

The ice limits in the tributary valleys west of the lake in the Eyre Mountains are neither well defined nor dated. An assumed upper ice limit of c. 500 m a.s.l. at Halfway Bay (based on down-valley ice profiles by Matthews (1967)) would push a diffluent ice tongue into the valley between Bayonet Peaks and Cecil Peak (see Fig. 1) where glacial moraine is preserved. The down-valley limits of the Lochy and other valley glaciers are not known. Lakes Nigel and Ned are moraine-dammed in part, but their barriers are also partly rock falls. It is assumed that these lakes are Late Otiran in age, as there are further moraine deposits higher in the Lochy headwaters, including well-preserved cirque moraines which are almost certainly of post-glacial age. No moraines of Late Otiran age are known in upper Eyre Creek, but may be preserved in the head of the Ashton Burn. Most if not all of the minor cirques of the Eyre Mountains were probably ice-occupied in Late Otiran time. Well-preserved lateral and terminal moraines in the Long Burn (Photo 6) and upper Billy Burn may also be Late Otiran, but could also date from a younger mini-advance at c. 6000 - 10 000 yesrs BP (before present day).

Early Otiran glacial advance, OI stage Q4, 60 000 - 70 000 years BP

The preceding ice advance also reached Kingston, but little of its terminal moraine is preserved. Most of it has been degraded, leaving only lag boulders and a subdued surface south of the more prominent Late Otiran moraine ridge. However, the extensive outwash plain draining south from there to the Kingston Flier station at Fairlight has a surface gradient which ties it back up-valley to a terminal moraine level higher than the Late Otiran moraine (and now represented by the deflated moraine and lag boulders), and on this basis it is inferred to be Early Otiran (O1 stage 4) in age. The dry meander which cuts this outwash plain (Photo 5) was probably formed late in the OI stage 4 advance as the ice began retreating up-valley.

Also at this time, a diffluent tongue of Wakatipu ice pushed into the Von catchment, leaving a magnificently preserved terminal moraine southwest of Mt

Nicholas, and an outwash plain draining south toward the South Von, the outwash stream from here cut a large meander into older outwash and into the Oreti catchment. During ice retreat from this event, an ice-dammed lake formed and cut a prominent lake bench on the northeast side of the terminal moraine.

Ice from the Wakatipu glacier would also have pushed up-valley into the lower Lochy, but no deposits associated with this ice level are known, apart from a small gravel deposit in the lower Long Burn. The down-valley limit of Q4 ice from glaciers in the head of the Lochy is not known, as no deposits are preserved.

Waimean glacial advance, OI stage Q6, 130 000 - 180 000 years BP

Identification of glacial deposits of this age is tenuous, because these deposits are outside the range of radiocarbon dating. Mapping and correlations are based on degree of preservation of surfaces, relative heights of moraine and outwash deposits,and tracing of down-valley terrace profiles into the Mararoa - Te Anau catchment.

There are no well-preserved moraine deposits associated with this advance in the Mataura catchment, but a terrace remnant at Greenvale Station is identified as a Q6 deposit. Other terrace remnants on the same profile are preserved at and down-valley from Athol. In the Von-Oreti catchment, Wakatipu ice reached the South Von, where extensive moraine is preserved with an accompanying outwash plain which now forms the McKellar Flats. This ice was linked to the Greenstone Valley via both the main Wakatipu trough, and the North Von valley over a low saddle. Another diffluent tongue from the Greenstone glacier reached the southern end of the Mavora Lakes trough, where it forms a well-preserved terminal moraine with prominent kettle holes (Turnbull & Forsyth 1988, Fig. 34) and an associated plain in the Mararoa River valley. At this time, it is likely that most of the larger valleys within the Eyre Mountains were ice-filled, and the high ridges supported many small cirque glaciers.

Waimaungan glacial advance, OI stage Q8, 250 000 - 300 000 years BP

No moraine or outwash deposits of this age are known from the Mataura catchment, and are presumed to have been stripped out by younger advances and accompanying erosion. The down-valley Q8 ice limit shown in Fig. 3 is thus inferred from the upstream limit of older deposits of Stage Q10 (but note that all these correlations are tentative, due to the lack of absolute dating).

Extensive outwash plains in the Oreti and Mararoa valleys are correlated with this glacial period, but no major Q8 valley moraine is known within the Eyre Mountains region. However, all the high cirques, including those on southern Eyre Mountains ridges, would have been occupied by ice.

Moraine deposits in the upper Mataura may date from this period, or may be younger. The lower reaches of the upper Mataura, upstream from Robert Creek, have classic interlocking spur topography, showing this reach to have been ice-free for some time. Very old alluvial fan deposits (mapped as eQf on the 1:50 000 map) may be of this age or older.

Nemonan glacial advance, OI stage Q10, 340 000 - 360 000 years BP

A high-level degraded terrace on the eastern side of the Oreti Valley at the mouth of the Ashton Burn is the only deposit in that catchment correlated with this advance; the gravels in it are somewhat more weathered than in younger units. In the Mataura catchment, probable Q10 age lateral and possibly terminal moraines are preserved on the high terraces east of Fairlight (on Lorn Peak Station) and Garston, with outwash terraces further downstream toward Parawa.

Ice would have occupied all the central Eyre Mountains valleys, and the headwaters of the upper Mataura, Robert Creek, and Eyre Creek as well as the tributaries of the Oreti such as the Ashton Burn. If the ice limit inferred for Stage 10 shown on Fig. 3 is correct, the upper Mataura valleys would have been the site of a glacially-dammed lake; no evidence has been found to confirm this, and possibly the Q10 ice limit lay upstream around Greenvale, allowing the upper Mataura drainage to run along the hill south of Fairlight. Remnants of outwash gravel are preserved on that hill slope, but their age is unknown.

OI stages 12 and older (430 000 - 500 000 years BP)

The only deposits known from these advances are within the Mataura catchment, downstream from Garston. It is possible that the ice level around Fairlight at this time reached the low saddle leading to Quoich Creek, with possible Q12 or older outwash gravels preserved in that valley. Weathered glacial debris probably older than OI stage 12 is preserved at heights up to 880 m a.s.l. on the Hector Mts east of Fairlight, and southeast of Athol. However, there is no direct evidence, from topography or preserved gravel deposits, that the proto-Mataura River ever flowed southwest past Mid Dome on to the Five Rivers plain (cf. McIntosh et al. 1990). With ice at these levels, glaciers would, however, have infilled the upper Mataura, Robert Creek, Eyre Creek, and certainly all the central valleys of the Eyre Mountains, and only the highest peaks and ridges would have been ice-free.

3.2 LANDSLIDES

Large-scale landsliding is a feature of much of the schist terrain of Otago and Southland, and the eastern Eyre Mountains include several major landslides. The slopes east of Robert Creek, east of Allen Creek, and above the Long and Short burns are all major complex landslides. Many other landslides are also present in the eastern Eyres; most are too small to show on the 1:250 000 scale map on which Fig. 2 is based, but they are mapped in detail on the 1:50 000 scale data record maps held by GNS.

These large and complex slope failures are characterised by hummocky topography, a lack of blocky bluffs and steep rocky faces, sometimes actively eroding scarps, and small springs and wet flushes (Photo 7). They are controlled by down-slope failure on schistosity planes within the underlying rock, often released in the head region by pulling apart along joint planes. Gravitational collapse following removal of ice support, especially in deep narrow valleys such as the Short and Long burns, was probably the major factor inducing initial movement. Subsequently, large earthquakes and/or high groundwater pressures provoked continued movement down the glacially oversteepened slopes. Episodic movement continues to the present time by downslope creep, rotational slumping, and debris flows.

Other, smaller landslides are mapped in Cascade Creek, in the upper Lochy, and in the serpentinite belt in the southwest. The central Eyres have fewer landslides, as the rocks are less schistose and stronger and foliation is generally flat, a much more stable configuration. Dipping foliation in the upper Lochy makes this area landslide-prone, but the absence of landslide deposits is attributed to more recent ice erosion; the large landslides of the eastern Eyres may date back for several hundred thousand years, as has been demonstrated elsewhere in Central Otago (McSaveney et al. 1992).

Smaller landslide deposits snapped in the upper Lochy, and occurring elsewhere, are inferred to be block falls, caused by catastrophic collapse of bluffs or oversteepened slopes. They are characterised by fan-shaped or semicircular accumulations of large to small angular boulders spread out over the valley floor and often over-riding older deposits. They are more common in regions where foliation is flat-lying and bluffs are steep and high.

3.3 VALLEY FLOOR ALLUVIUM, SCREE AND ALLUVIAL FAN DEPOSITS

All the major and minor valleys of the Eyre Mountains contain deposits of post-glacial stream alluvium. In the Lochy, these deposits include the stepped terraces about Halfway Bay homestead, and terrace remnants in the upper valley. An aggrading alluvial plain in lower Robert Creek is probably related to higher erosion rates in that catchment, in turn related to the large landslide on the east side of the valley. Recent aggradation in the streams south of the tipper Matauru (Photo 8) is related to erosion of the softer, more weathered rock in that region, related to the active scree slopes in stream headwaters. Alluvial fan deposits are widespread, and form at the mouths of side streams of all sizes. These fans grade out and down-valley into terraces with flatter profiles, and the distinction is made on slope angle as much as different gravel properties within them. Both fans and terraces are more fertile, easier to fence and graze than steeper pill slopes, and consequently are the most developed areas within the Eyre Mountains.

Extensive scree deposits are a feature of the central Eyre Mountains (Photo 9), draping the bluffy topography and grading out on to the valley floors. Screes also mantle the slopes of most high cirques. Scree debris ranges from loose fine material in areas of higher schist grade, to coarse, blocky screes in the greywacke-dominated area such as around Eyre Peak (Photo 9). The scree deposits are inferred to be many thousands of years old, dating from the last glaciation (Q2) or beyond. The ridges on Mataura Valley Station between Eyre Creek and the upper Mataura are also mantled by scree, deeper and finer than elsewhere (Photo 8). This difference is attributed to the area having been ice-free since the early Quaternary, with consequent deeper weathering of the underlying rocks.

4. Sites of geological value and interest

Within the Eyre Mountains and surrounds, two sites have been identified as being geologically or geomorphologially significant; the Kingston Moraine and the Mavora Lakes terminal moraine (Priestley 1990; Kenny et al. 1993) (see Fig. 1). Both these sites are mentioned in geological guide books (Brockie 1973a, 1973b; Turnbull & Forsyth 1988). The significance and value of the Kingston Moraine has also been mentioned in a previous summary report to DOC (Turnbull 1995; Appendix 3).

Recent geological fieldwork reinforces the importance of these sites in terms of their landscape, geomorphological and glacial geology values. Both are readily accessible and visible from roads, have very well-preserved geomorphology, and are key areas for interpreting glacial geology over the wider region.

The critical area for the Kingston moraine and outwash complex extends from the lake shore south to the Mataura River at Fairlight (see Photos 4 and 5), and to the hill slopes to east and west (Appendix 4). The glacial features beyond there, for example along the foot of the Hector Mountains, are more obscure and harder to see, and do not have the same well-developed morphology. The Kingston moraines and outwash plains are vulnerable to the effects of large-scale farm forestry or wilding pine spread, and any modification of the surfaces - by housing, growth of thick vegetation, or roading - will detract from their value.

The forested Mavora Lakes moraines are protected by virtue of being within the Mavora Lakes Park (conservation area), but the related tussock-covered outwash plains are not, and are already being modified down-valley by planting of shelterbelts and agricultural development. As a representative glacial landscape of considerable value, the Mavora Lakes area could be extended to cover the Von catchment, where the array of terminal moraines and outwash terraces is also very well preserved.

The basement rocks of the Eyre Mountains contain no known mineral, geological or structural features of particular merit. The area has an unusual appearance by virtue of its synformal structure and associated landscape, and very deeply incised glacial valleys. Although such features can be found individually in many areas (e.g. U-shaped valleys in Fiordland; flat-lying semischist in the Garvie Mountains), the combination in the Eyre Mountains is unique.

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Appendix 1: Glacial features at Kingston

Unpublished report to Department of Conservation (Turnbull 1995)

The terminal moraines and associated outwash plains and abandoned river channels at Kingston have been mapped at 1:250 000 scale by Wood (1962) and referred to by McKellar (1978); Brockie (1973) has provided details of the Quaternary development of the Kingston moraine. The area is referred to briefly in a geological guide book on the Queenstown district (Turnbull & Forsyth 1988)

GNS staff visited the area (January 1995) during fieldwork for a revised 1:250 000 geological map of New Zealand. Air photo interpretation and some field checking has been done, but the results of this work are still being plotted up and interpreted. These notes must therefore be regarded as interim only, and interpretations may be revised in the future.

The terminal moraines at Kingston, and the associated outwash gravel plains and dry river beds to the south, are undoubtedly the best examples of these glacial and fluvioglacial landforms to be seen from a main road anywhere in the Wakatipu basin. Similar landscapes occur in the Von-Oreti catchments southwest of Lake Wakatipu and in the Te Anau district, but are not as readily seen or interpreted.

Although apparently simple, the sequence of glacial events recorded at Kingston is complicated in detail and not yet fully understood. It appears that several glacial advances terminated at more or less the same place. The main and highest Kingston moraine ridge may date from a glacial advance prior to the last major glacial advance (the age normally assigned to the Kingston moraine). The outwash gravel plain (Trotters Plain, on NZMS 260 sheets F42 and F43) reaching south from this moraine was built during the same advance which produced the main Kingston moraine ridge. Subsequently, meltwater from ice-marginal lakes along the eastern side of the valley north of Kingston and from subsequent wasting Wakatipu Glacier, drained south via the dry river channel (at c. 370 m) at the eastern end of the moraine, the channel which is crossed by the main road just south of the moraine ridge.

The meltwater or lake outlet then have shifted to the western side of the valley, cutting into both the moraine ridge and the outwash plain, to form the now-dry river channel followed by the Kingston Flier railway line. The shift may have been influenced by the eastern outlet becoming blocked by alluvial fan material building out from the slopes of the Hector Mountains above. The outlet probably used the western route for some time, to erode to a level of c. 350 m - lower than the original outlet. This outlet is now blocked, at its northern end, by either younger moraine or landslide debris.

The Kingston moraine ridge has a lake bench eroded into the north side of it, at a height of around 330 m; Kingston is sited partly on this bench. The lake outlet at the time this bench was formed was not to the south, but was via the present Kawarau River. Whether the blocking of the southern outlet was the cause of the diversion into the Kawarau River, or whether the Kawarau captured the drainage, is not known.

Glacial features of note in the Kingston area are at two scales; the larger, valley-wide features of moraine ridges and outwash plains, and smaller features such as the dry river beds crossed by the road and railway, and the scattered glacial erratic boulders on the moraine surface which provide evidence of its glacial origin. (A glacially-striated boulder from the Kingston moraine is preserved outside the Otago Museum in Dunedin). Subtle features on the south side of the Kingston moraine have been interpreted as forest dimples (upturned soil heaps left after trees have been toppled in windstorms) (Brockie 1973). Although similar landscape features exist elsewhere, none are so well displayed or in such close proximity to a major tourist route.

From a geological point of view, it would be desirable for the glacial landscape of the Kingston area to be preserved, as it is readily seen from a main tourist route (or the Kingston Flier), and could be used as the basis of interpretive or educational displays (see reference to the Queenstown geological guide book, above). The main danger to the landscape, at all scales, would seem to be from the obscuring effect of either spreading wilding pines or large-scale farm forestry development. Small-scale features like forest dimples, and erratic boulder heaps, are of course destroyed by cultivation.

References:

Brockie,W.A. 1973: Quaternary history of southern Wakatipu and the upper Mataura Valley *and* Terracettes and dimples on the Kingston Moraine *in* International Union for Quaternary Research Guidebook for Excursions A8 and C8. IX *INQUA Congress, Christchurch.*

McKellar, I.C. 1978: Lake Wakatipu and Southland Plains. Pp. 614-617 *in The Geology of New Zealand, Vol.* 2. Government Printer, Wellington.

Turnbull, I.M.; Forsyth, P.J. 1988: Queenstown - a geological guide. *Geological Society of New Zealand Guidebook No. 9.*

Wood, B.L. 1962: Sheet 22, Wakatipu. Geological Map of New Zealand 1:250 000. Department of Scientific and Industrial Research, Wellington.

Appendix 2: Figures

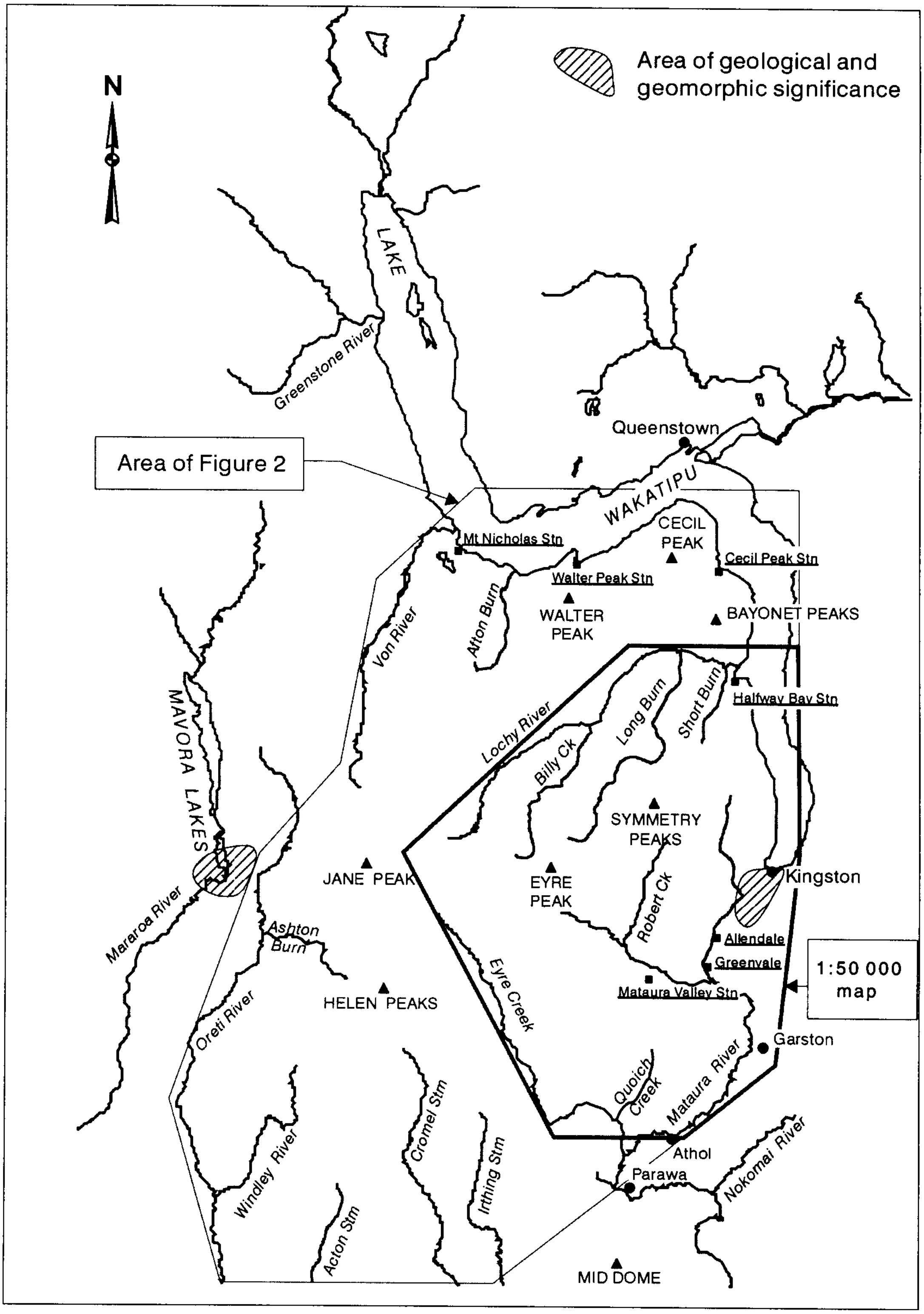

Figure 1: Location map for the Eyre Mountains, showing geographic features mentioned in text, and location of areas with geological and geomorphological significance.

GEOLOGICAL MAP OF THE LYRE MOUNTAINS

Figure 2: Simplified geological map of the Eyre Mountains, scale 1:250 000, after Turnbull (2000 in prep.)

Key overleaf.

Surficial geology:

	(Rock type)	(Age)
Q1f	Alluvial fan gravel	Post-glacial (<14000 yrs)
Q1a	Terrace and valley floor alluvium	
Q1b	Beach gravels	
Q1s	Scree deposits	
	Large landslides	all ages within Quaternary
uQt, uQo	Till and outwash of undifferentiated cirque glaciers	probably post-glacial (<14000 yrs)
Q2o	Outwash gravel associated with the Kingston moraine	Late Otira Glacial
Q2t	Kingston Moraine - bouldery till	
Q4o	Outwash gravel from older Kingston moraine	Early Otira Glacial
Q4t	Deflated Kingston moraine - bouldery till and boulder lag	
Q6o	Outwash gravel in remnant terraces	Waimea Glacial
Q10t	Weathered bouldery till in terraces near Lorn Peak Station	Nemona Glacial
Q10o	Outwash remnants associated with Q10 till	Mid-Early Quaternary
Q12o	Weathered high level outwash gravels	
Q16t	Weathered possible till remnant	
eQf	Weathered fan gravels	

Basement geology:

Yc, Ycs	Non schistose greywacke and mudstone (Yc) with some bedding, massive greywacke (Ycs) SW of South Von Fault	Permian; metamorphosed in Jurassic - Cretaceous
Ycc, Yc2A, Ycs2A	Weakly schistose greywacke and slate; conglomerate bands (Ycc) and slightly schistose sandstone (Ycs2A) SW of South Von Fault	
Yc2B, Ycs2B	Slabby, schistose greywacke and slate with good cleavage; schistose sandstone (Ycs2B)	
Yc3A, Yc3Ap	Schist with quartz veining and flattened bedding; meta-mudstone dominates SE of Kingston (Yc3Ap)	
	metavolcanics	
	conglomerate bands	

Geological Symbols:

	Synform in schistosity (dotted = concealed)
	Antiform in schistosity (in lower Lochy River)
	Major fault (dashed = inferred; dotted = concealed)
	Isotect (between schist grades)
	Attitude of foliation

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