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ABSTRACT

The Learning in Science Project has adopted the view that science teaching might be improved if teachers can be given some appreciation of students' views of the world and the beliefs, expectations, and language that learners bring to new learning situations. This investigation compares and contrasts views that children and scientists have on several aspects of glaciation in New Zealand. Individual interviews were conducted with 37 students during which they observed colored photographs of various, well-known New Zealand landforms (including scenes of the Tasman glacier and Milford Sound, a glaciated landform) and described what they saw. Questioning was then directed toward eliciting their ideas concerning processes behind the two glacier phenomena. Sample responses are presented related to such questions as: What is a glacier? Do glaciers move? What is the depth of glacial ice? What is a moraine? How did Milford Sound originate? What is the nature of the water in Milford Sound? Responses indicate that the majority of students do not realize that glaciers are bodies of ice which have a tendency to move and that they are unaware of the major erosional properties associated with glaciers. (JN)

SCIENCE EDUCATION RESEARCH UNIT

GLACIERS

University of Waikato
Hamilton, N.Z.

WORKING PAPER 203

GLACIERS

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Working Paper

The Science Education Research Unit at the University of Waikato emerged from the research activity generated by the original Learning in Science Project (1979-1982). The aim of the unit is to facilitate and encourage Science Education Research.

One of the most successful innovations of the Learning in Science Project was the production of working papers whereby research findings could be shared with practising teachers and curriculum developers. This present series of papers (the 200 series) continues that tradition for research undertaken by members of the Unit but which does not form part of the Learning in Science Project.

We would welcome comment or information related to the topic of this paper.

Roger Osborne

DIRECTOR, S.E.R.U.

INTRODUCTION:

Teachers frequently encounter situations whereby students seek to rote-learn definitions and mechanical 'rules of procedure' without really being able to relate their acquired words or rules to information that they already possess and understand. White (1981) has expressed this succinctly:

> "Maybe your students are doing well at examinations, but do they really understand the science concepts and principles you teach them? Recent application of new methods for probing understanding reveals that apparent success in learning often masks gross misunderstanding on a scale not previously imagined."
>
> (p1)

A number of workers (Osborne and Gilbert, 1980; Gunstone et.al., 1981, Gilbert et.al., 1981) have demonstrated that many children and adolescents hold ideas, concerning 'force' and 'motion' which tend to be far removed from the scientists' view of Newtonian physics, e.g. heavier objects are seen (by many learners) to fall faster than lighter objects. This is but one way in which the learner may perceive and interpret the world in light of his/her day to day experiences.

Other investigations into aspects of student (mis)understanding, in physics, have been conducted by Osborne, 1981; Stead, 1980(a) and Stead and Osborne, 1981. Similar studies have taken place with a focus on areas of chemistry (Happs, 1980; Schollum 1981) and biology (Stead, 1980(b); Stead, 1980(c)). Such research has led workers to predict that the ideas, views and expectations that students have, prior to formal instruction, are quite likely to influence later learning.

The Learning in Science Project (Freyberg, Osborne and Tasker, 1980) has maintained the view that science teaching, across all levels, might be improved if teachers can be provided with some insights into the beliefs and ideas that children and adolescents take with them to the learning environment. It should be stressed here that the Learning in Science Project has not adopted an evaluative stance, rather it has used small-scale, in-depth studies to probe conceptual 'difficulties' and to arrive at some conclusions which can readily be related to science teaching.

Practising earth scientists and secondary teachers (see Happs, 1981(c)) have identified the topic 'landforms' as being an important teaching area, within the earth sciences, and this topic is included in sections 4 (level 4) and 8 (level 5) of the science: Forms 1-4 Draft Syllabus. The relevant extracts from this syllabus are shown in Appendix A.

This investigation considers the topic 'landforms' and looks at some aspects of student understanding of glaciation and its effects. Research into students' prior knowledge and (mis)understanding, in areas within the earth sciences, has already been undertaken (Moyle, 1980; Happs, 1981(a); Happs, 1981(b)). This current paper will, hopefully, contribute further to our understanding of learning difficulties in the earth sciences.

An attempt has been made to compare and contrast the views that learners have, concerning the Tasman glacier and Milford Sound, with those scientifically acceptable views. In this way, it may be possible to arrive at some 'measure' of student understanding in this area, so that later teaching strategies can be directed towards modifying, or adding to, the student's existing body of knowledge.

THE EARTH SCIENTISTS' VIEW OF GLACIATION

It will always prove useful and appropriate to consider the ways in which the earth scientist might look at aspects of glaciation. This will enable teachers to make some comparison between the scientists' views and the views of children and adolescents. Comparisons, of this nature are summarised within this paper.

WHAT IS GLACIATION?

The everyday term 'ice age' refers to periods of glacial advance or glaciations.[1] The glaciation theory (now universally accepted) suggest that large ice sheets have, in the past, covered large areas of the Earth and that the present-day ice-caps of Greenland and Antarctica are merely the remains of vast continental ice-sheets.

New Zealand has been significantly affected by past glaciation processes with extensive glacier ice modifying much of the South Island and marginal (periglacial) activity influencing some parts of the North Island.

[1] The glossary, in Appendix B, offers an explanation of those terms that are commonly used by the earth scientist and which are pertinent to this paper.

WHEN HAVE ICE AGES OCCURRED?

Several cycles of glaciation are known to have taken place worldwide with at least three main glacial phases occurring during the Quaternary period (the last two million years). The last glacial maximum appears to have climaxed approximately 20,000 years before present (B.P.), and was finished by about 10-14,000 years ago.

We are currently living in a mild (interglacial) part of a glaciation cycle and, evidence suggests, that over the next 20,000 years glaciers and continental ice-sheets will return to New Zealand and other parts of the world. Continental glaciations are not common events in Earth history, having occurred only, at times, during the Quaternary (two million years B.P. to the present), Permian (280 million to 230 million years B.P.), Carboniferous (340 million to 280 million years B.P.), Ordovician (500 million to 430 million years B.P.) and the Precambrian (more than 600 million years B.P.)

It would appear that the 'normal' climate, for the bulk of time from the Cambrian (600 million to 500 million years B.P.) to the present, has been milder than the climate over the past few million years.

WHAT CAUSES THESE 'RARE' GLACIAL CONDITIONS?

Because ice ages are such rare events in Earth history, it would appear that they have been 'triggered' by a special combination of conditions. The cause of ice ages seems to stem from the presence of a large land mass in a polar position, e.g. Antarctica. The fluctuation from glacial-interglacial results from climatic change and there is little doubt that a relatively slight decline in present day average annual temperatures, over large areas of earth, would lead to a return of glaciation. The overall average annual temperature differential between a 'normal' and a glacial climate is only approximately 10°C and a fall of 4-5°C from the present global mean annual temperature could lead to the onset of continental glaciation.

Many hypotheses have been proposed to explain glaciations and these include:

(i) Terrestrial influence: e.g. volcanic dust; changing land and oceanic areas, which affect ocean currents; changing heat flow from the Earth; mountain building, which affects atmospheric circulation; changing absorption of the Earth's atmosphere.

(ii) Astronomical influence: e.g. changes in solar radiation; variations in the eccentricity of the earth's orbit; changes in density of hydrogen gas in space, through which the solar system is travelling.

WHAT IS A GLACIER?

A glacier is a body of ice which is essentially made up of recrystallised snow. All glaciers have their origin as snow and it is the change from 'fluffy' white snow to dense blue ice which occurs in the high snowfields. Drillholes in these snowfields will reveal a succession of layers of increasing density as the overburden of snow squeezes out trapped air until clear ice is formed.

There are four kinds of glaciers:

(i) Cirque Glaciers: These are very small glaciers which occupy hollow, armchair-shaped recesses high in a mountain. Such recesses are caused by physical weathering and erosion.

(ii) Valley Glaciers: These are glaciers which flow downward to occupy a valley. They may vary in size from no more than a few hectares, to large tongue-like masses, many tens of kilometres in length.

(iii) Piedmont Glaciers: These glaciers are found in lowland areas at the base of a mountain. They are formed by the coalescence of one or more valley glaciers.

(iv) Ice Sheets: These are vast glaciers, usually 2-3 km thick, which can blanket a large land surface.

ARE THERE MANY GLACIERS IN NEW ZEALAND?

Most New Zealanders have heard of the more accessible glaciers such as the Tasman, Fox and Franz Josef, but few people realise that there are over one hundred glaciers in the Mount Aspiring National Park alone. Over one-third of the Mount Cook National Park is made up of permanent snow and glacial ice and more than sixty named glaciers are to be found in the Westland National Park. Other 'active' glaciers are to be located in the Waimakariri watershed, within the Arthur's Pass National Park. No glaciers exist in the North Island of New Zealand.

WHAT SORT OF GLACIER IS THE TASMAN GLACIER?

Located within the Mount Cook National Park, the Tasman glacier typifies a valley glacier which originates from a mountain snowfield, to flow down through a valley. This glacier once covered an area far beyond its present boundaries. The Franz Josef glacier is another example of a valley glacier.

DO GLACIERS MOVE?

When snow is compacted to form ice in a mountain-top depression, it will accumulate as precipitation continues at high altitude. This accumulation of ice continues until it overflows. The movement of ice (flow) occurs because of the gravitational force on the glacial mass which results in sliding of the whole body (on a wet base), as well as creep, i.e. slipping within the ice crystals themselves.

Glaciers are sensitive indicators of climatic change and glacier recession has been taking place, worldwide, over the last 200 years.

WHAT IS THE RATE OF GLACIER FLOW?

The rate of movement varies from one glacier to the next. The rate also varies from one section of a glacier to another, it being faster in the centre than along the side. Glaciers are likely to move faster when the valley, which they occupy, becomes narrower.

Daily advances of almost two metres have been measured for the Franz Josef glacier whilst the Tasman glacier is moving at a rate of approximately 60 centimetres per day.

WHAT IS THE DEPTH OF GLACIAL ICE?

Ice thickness will vary from glacier to glacier and also depends on where the depth is measured in a particular glacier. However, a consideration of the way in which glaciers have occupied and re-shaped existing valleys will indicate the great volume of ice involved. A depth of approximately 700 metres has been recorded in the Tasman glacier ice with the Franz Josef glacier having gained up to 120 metres of ice depth at the terminal face.

WHAT IS MORAINE?

Glaciers represent tremendous weathering and erosive forces which break up rock fragments and transport this rock waste in the form of moraine. This material is moved from the upper valley regions to the lower slopes where it is deposited, along with other material derived from intense physical weathering processes above the glacier.

Moraine consists of a range of material sizes, from fine wind-blown deposits to large rock-slabs weighing thousands of tonnes. On a single glacier, moraines tend to form lines of debris along each side. These deposits are called lateral moraines and, if two glaciers bearing lateral moraines meet and coalesce, the lateral moraines from the two margins result in a moraine in the middle of the glacier.

Some of the moraine will eventually reach the front of the glacier where it is deposited as terminal moraine. Such a deposit marks the glaciers farthest advance.

Much of the moraine will be reworked and re-deposited by rivers associated with the glaciers. In this way, the material forms outwash fans and plains, e.g. Canterbury Plains, with the wind transporting and depositing much of the finer material.

WHAT IS A CREVASSE?

This is a fissure in the glacial ice due to the influence of various strains. Where the glacier flows over an abruptly steepening slope the upper ice is subjected to tension and results in deep, gaping cracks which can be up to 50 metres deep.

HOW IS MILFORD SOUND CONNECTED WITH GLACIATION?

Any visitor to the Fiordland National Park, where Milford Sound is located, will witness very steep mountains and narrow valleys. This topography has resulted from recent geological processes which have led to the uplift of mountain ranges and intense glaciation during the last two million years. At least three main phases of glaciation have been recognised in this area and each phase is likely to have further modified the landscape, producing deeper valleys and 'sharper' ridges. All the main valleys, in Fiordland, were occupied by large glaciers which reached the coast in the west.

Valleys are usually cut before the glaciers form. Glaciers, unlike rivers, do not cut their own valley, rather they tend to occupy and modify them. A particularly well-known characteristic of a glaciated valley is its U-shaped steepened valley walls.

The cutting action of glaciers tends to modify existing valleys, carving them out well below sea-level to give the lakes and fiords.

WHAT IS A FIORD?

Milford Sound is an example of a fiord. These are long deep marine bays, having steep high walls along a mountainous coast. Fiords are typically found in Alaska, Norway and Fiordland. These features are glaciated troughs which have been partly submerged by the sea and result from glacial erosion to a depth of at least 300 metres. The actual depth of fiords result from:

(i) glacial erosion below sea-level;

(ii) rise in sea-level, following a glaciation;

(iii) Subsidence of the Earth's crust at that area.

Glacial erosion is likely to have the most pronounced effect on fiord development since sea-level is not a base-line for glaciers which enter the sea. Unlike rivers, glacial ice can continue to erode its bed to a great depth and a 300 metre thickness of glacier ice is capable of bed erosion until it is submerged to a depth of 270 metres. At this point the glacier, being less dense than water, will float. Moreover, during glaciations, sea-level may drop by 120-140 metres below present levels due to the build-up of ice sheets.

The Cleddau glacier, which disappeared several thousand years B.P., most probably filled the Mil d Valley to a great depth, eroding the valley to a point well below the sea-level. This formed Milford Sound. Glacial excavation reached a depth of approximately 400 metres close to the rock known as "The Lion". The well-known form of Mitre Peak has been carved and modified by the main Milford glacier and, in part, by a large glacier which moved down Sinbad Valley to link up with the main ice flow.

THE INVESTIGATION:

Thirty seven students (6 x F1, 5 x F2, 5 x F3, 6 x F4, 4 x F5, 6 x F6[2], 5 x F7[3]) from seven co-educational schools, were individually interviewed.[4] Each student was chosen for interview by his/her teacher who was requested to select students who were considered to be of "average scientific ability".[5]

Not all students from any one level, in this investigation, were interviewed at the same school. In this way the student samples, across each age range, were kept as heterogeneous as possible.

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[2] Form 6 students took the following subject options:
601 = maths, physics, chemistry, biology, English.
602 = maths, physics, chemistry, technical drawing, English.
603 = maths, applied maths, physics, chemistry, English.
604 = maths, biology, chemistry, accounting, English.
605(g) = maths, physics, biology, geography, English.
606 = maths, biology, typing, accounting, English.

[3] Form 7 students took the following subject options:
701 = maths, physics, chemistry, biology, English.
702 = maths, applied maths, physics, chemistry, English.
703 = maths, applied maths, physics, chemistry, English.
704(g) = biology, history, geography, English.
705(g) = maths, applied maths, physics, geography, accounting.

[4] F1 - F7 = Forms 1 - 7, i.e. (11 - 17 year olds).

[5] The investigator considered that students were generally average to slightly above average ability in most instances.

Each interview had a duration of approximately 30-45 minutes during which time the student was shown a number of 25 cm x 20 cm coloured photographs of various "well-known" landforms, located within New Zealand. Two of these photographs were of the Tasman glacier and Milford Sound. These scenes being representative of both present-day 'active' glaciation and a resultant glaciated landform. Only these two landforms will be discussed within the scope of this paper.

Students were asked to describe each landform in turn and to identify the feature if possible. Questioning was then focussed on the students' ideas which they might hold about the 'processes' behind the phenomena of both glacier and glaciated landform. It was emphasised that what was required was each student's personal thoughts and ideas about the scenes and that there would be little importance placed on whether their responses were scientifically 'correct' or not.

Each interview was held in an informal and non-threatening atmosphere throughout, with students being informed of the purpose behind the interview and the desirability of using a tape-recorder.

A number of cards were shown to students at the end of the discussion phase. A stimulus word[6] was written on each card so that students could be given the opportunity to provide information, in addition to that given when discussion centred around the photographs.

RECOGNITION OF THE TASMAN GLACIER

It was anticipated that few (if any) students would be successful in identifying the Tasman glacier by name because of the similarity in appearance of many glaciers. Furthermore the question "Do you recognise that scene?" is likely to be experience-specific since not many students would have witnessed that particular glacier first-hand, nor have seen many aerial photographs of the same.

Only three students (1 x F4, 2 x F6) were able to identify the scene as being the Tasman glacier, although a further twelve students (1 x F1, 1 x F2, 1 x F4, 1 x F5, 3 x F6, 5 x F7) correctly identified the feature as being a glacier, without being able to name it.

[6] Words which were pertinent to this investigation, etc.

Where the photograph was not identified as representing a glacier, students were prepared to state what they considered it to be:

"A road covered in snow and/or ice." (3 x F1, 2 x F2, 2 x F3, 3 x F4, 2 x F5, 1 x F6)

"A frozen river." (2 x F1, 1 x F2, 1 x F3)

"Snow and/or ice on a hillside." (1 x F2, 1 x F3)

Some individual ideas were:

"A salt river." (302)

"An avalanche." (402)

"A lava flow." (503)

Those students who were not able to identify the glacier, by name, were later told what the scene was and the name of the glacier given.

Five students (3 x F1, 2 x F3) claimed they had never heard of the Tasman glacier whilst only two students (2 x F1) were not aware of the term 'glacier' and were unable to provide any information about them.

WHAT IS A GLACIER?

Although the vast majority of students recognised the term 'glacier', their definitions were quite varied and generally simplistic. Discussion was centred around the photograph of the Tasman glacier and, later in the interview, by means of the stimulus-words. Some responses to the question "What is a glacier to you - in your meaning of the word?" were:

"A whole lot of ice." (1 x F2, 1 x F3, 3 x F4, 1 x F5)

"Moving ice." (1 x F5, 2 x F6, 2 x F7)

"Ice coming down a mountain." (2 x F2, 1 x F4, 1 x F5, 2 x F6)

Some explanations were not so accurate:

"A frozen river." (3 x F1, 1 x F4)

"Something to do with ice." (1 x F2, 3 x F3)

"Snow on a mountain." (305)

"Moving rock with ice on top." (502)

"A thing of ice that has come out of the sea." (103)

Seven students (1 x F2, 1 x F4, 2 x F6, 3 x F7) were able to provide responses which were a little more 'scientific'.

"A big cut in the ground - the ice has filled it up." (202)

Reference was made to ice moving down a mountain, by six students (2 x F2, 1 x F4, 1 x F5, 2 x F6):

J "It's (a glacier) a whole lot of moving ice that moves because it's so heavy that it just flows down a mountain."

I "Where does it come from in the first place?"

J "From the top of mountains." (501)

I "What does that word 'glacier' mean to you?"

H "Sort of - a sheet of ice that's running down a mountain - and it's gradually turning into water at the bottom." (606)

Four students (1 x F4, 1 x F6, 2 x F7) indicated that a glacier, such as the Tasman glacier, is likely to occupy a valley:

I "What do you understand by that term 'glacier'?"

C "Well - a frozen ice mass down a - umm - a mountain valley - which moves or recedes - depending on the temperature - what have you." (703)

"A valley with a whole lot of ice." (402)

Three students (2 x F6, 1 x F7) felt that glaciers were responsible for cutting the valleys they occupy:

"It (glacier) cuts away the - when it's finally gone you can see a valley - you know - what is left." (601)

I "Now this word 'glacier' - what does that word mean to you?"

A "Well to me it means that there's a - at one time there's been a - a large amount of ice which has gradually been pushing the rock - gouging its way through the mountains." (605(g))

Two students (2 x F6) made reference to the shape of the valley after its occupation by a glacier:

T "You can see a valley you know - when it's left."

I "How would you recognise these valleys?"

T "They are either V-shaped or U-shaped - I don't know." (601)

"It's (glacier) ground a lot of rocks into a fine pulp and it's left a large U-shaped valley." (605(g))

DO GLACIERS MOVE?

The mass of ice was seen to be moving in some way, by 26 students (3 x F1, 4 x F2, 5 x F4, 3 x F5, 6 x F6, 5 x F7).

The situation was well perceived by one of the younger students:

> "It's (glacier) sort of a lot of ice that's moved over centuries - slipped slowly - and sometimes they retract and can leave lakes." (106)

also,

> "I suppose it's just a flow of ice." (504)

Nine students (3 x F1, 2 x F2, 2 x F4, 2 x F6) likened the glacier movement to a stream on a mountainside, i.e. one-way flow down to the base.

The idea of a frozen river was stated explicitly:

> "It's (glacier) a frozen river and there's lots of ice around and I think the water might move underneath it." (101)

I "Tell me more about a glacier."

A "All I know is that it moves slowly like a river - but ice."

I "Where does the ice come from - do you think?"

A "The water comes down the slopes - it's so cold it freezes." (406)

Five students (2 x F2, 2 x F4, 1 x F5) considered that the glacier movement would be largely determined by whether, or not, snow fell directly on to the glacier. Conversely, the glacier was seen to get smaller in hot weather:

> "Down the bottom - in sort of hot weather it all breaks off. That's how it goes way back." (201)

> "In summer it (glacier) melts." (403)

The idea of a glacier simply slipping down a mountainside was put forward by one student (1 x F4).

S "It (glacier) sort of keeps slipping."

I "Keeps slipping? Which way."

S "It keeps coming down lower." (404)

One student (1 x F5) thought that the glacial ice did not move itself, rather it was carried along on a section of moving land:

> "It's (glacier) a moving piece of land with snow and rock and all that - it's all moving." (504)

Five students (5 x F3) failed to see the possibility of any movement from a glacier:

I "Do you think that's (glacier) moving?"

L "It doesn't look to be." (302)

The notion of glaciers having been formed during "an ice age" and surviving up to today, was mentioned by one student (1 x F2):

"It (glacier) might have formed in the ice age."

This "ice age" was confused with that period of geological time which followed the extinction of dinosaurs (this latter period was approximately 60 million years B.P.).

"The ice age was that age after the - age of dinosaurs." (202)

Ten students (2 x F5, 4 x F6, 4 x F7) were able to discuss possible mechanisms for glacier movement. These fell into four categories and revealed some good 'scientific' insight.

(i) Gravitational Control: (1 x F6)

I "What causes them (glaciers) to move - do you think?"

R "I think it's just gravity." (604)

(ii) 'Pressure' of Snow and Ice on Mountain: (1 x F5, 1 x F6, 1 x F7)

I "What causes it (glacier) to move?"

T "Pressure from further back - you know - more ice." (601)

(iii) Base of Glacier Liquifies: (1 x F6)

"The weight of the snow on top is - umm - what does it do? - The pressure on the top makes the lower stuff liquid - slightly liquid and they flow forward." (603)

(iv) Climatic Control: (1 x F6, 4 x F7)

"Well - frozen ice mass down a mountain valley - which moves or recedes depending on the temperature and - what have you." (703)

WHAT IS THE DEPTH OF GLACIAL ICE?

Twenty students (3 x F1, 4 x F2, 3 x F3, 3 x F4, 2 x F5, 2 x F6, 3 x F7) stated either that they did not have any ideas about the depth of ice in a glacier, or else they were not prepared to estimate any depth.

Seventeen students felt confident about making some estimate of ice depth and these ranged from "a few millimetres" up to "200 feet".

(i) Less than one Metre

Seven students (1 x F1, 1 x F2, 1 x F3, 2 x F4, 1 x F5, 1 x F7) felt that the glacial ice would not be very thick at all:

W "A few millimetres."

I "A few millimetres - and then what would there be?"

W "There would be black rock." (502)

I "If we could land on there (glacier) with an aircraft - and drill down into the ice - how far down do you think we'd go?"

C "Oh - I don't know."

I "You couldn't say whether it was a long way or a short way or ...?"

C "Oh - it would be a short way, I think."

I "A few centimetres or a few metres - or ...?

C "Oh, no - it would be about - a couple of feet." (701)

(ii) Between 1-5 Metres:

One student (1 x F6) made an estimate of a few metres. The actual depth of ice was not specified and may have been outside this range of 1-5 metres.

D "Not very (deep) - I don't think."

I "Not very?"

D "It would be pretty shallow - I think there's a river underneath it (glacier)."

I "A few centimetres - a few metres - a few hundred metres - or ...?"

D "No - a few metres." (602)

(iii) Between 5-10 metres:

Five students (1 x F1, 1 x F3, 1 x F4, 1 x F6, 1 x F7) placed their estimates in this range.

"Twenty feet and then rock." (402)

"Very deep I would think - umm - judging from the one I've seen it's probably twenty-odd feet or something like that." (702)

(iv) More than 10 metres:

Two students (1 x F1, 1 x F6) considered that the glacier ice would exceed ten metres in depth:

I "If we could jump out of our aircraft with a drill - and drill down into that ice - what depth do you think we would go through the ice? Any ideas on that?

P "Oh, about fifty feet."

I "And then what would we hit?"

P "Probably just rock." (106)

I "How deep do you think the ice would be?"

R "Oh - I don't know really - umm - it would be about - umm - about a hundred feet or so."

I "Then what would there be?"

R "Probably just ash or rock or something." (604)

Two students (1 x F5, 1 x F6) were not prepared to quantify their estimates of ice depth although they expressed a belief that glaciers are not 'shallow phenomena'.

"Quite a way." (504)

"Pretty deep." (601)

WHAT IS MORAINE?

A search was made for an understanding of the term 'moraine' to ascertain whether, or not, students saw moraine as an important glacial deposit. Such deposits were pointed out on the photograph of the Tasman glacier, in order to elicit a suitable response. Following the discussion of the photograph, the word 'moraine' was presented on a card.

Twenty nine students (5 x F1, 5 x F2, 5 x F3, 6 x F4, 3 x F5, 2 x F6, 3 x F7) were unable to provide any sort of definition of the term 'moraine'.

One younger student (1 x F1) confused the term 'moraine' with a more everyday word:

"I've heard of moraine pudding." (106)

One, more experienced student, (1 x F6) considered that moraine was a deposit of another kind:

"A deposit left by landslides." (606)

Six students (1 x F5, 3 x F6, 2 x F7) were confident that moraine was left by glaciers. These students were able to identify moraine on the photograph and comment about the word 'moraine':

> "Debris and stuff that's been scraped off the bottom of mountains and off the sides of mountains, by a glacier." (704(g))

WHAT IS A CREVASSE?

The idea of crevasses on glaciers was explored by referring students to the crevasses that were visible on the photograph of the Tasman glacier, and by the presentation of a card with the stimulus-word 'crevasse' printed on it.

Fourteen students (4 x F1, 2 x F2, 4 x F3, 2 x F4, 2 x F5) had never heard of the term 'crevasse', whereas the remaining students offered the following categories of explanation:

> "A large hole" - no reference to ice. (103, 403)
>
> "A hole in the ground." (202, 203)
>
> "Grooves or channels in rock." (204, 501)
>
> "Splits in a mountain." (701, 704(g))
>
> "A hole or gap in a rock." (402, 406, 604)
>
> "Part of a volcano." (503)

Eleven students (1 x F1, 1 x F3, 1 x F4, 5 x F6, 3 x F7) clearly associated the term 'crevasse' with snow and/or ice and most of these students made some reference to 'cracks' in the glacier.

RECOGNITION OF MILFORD SOUND:

The photograph of Milford Sound, including Mitre Peak, was immediately recognised by eleven students (1 x F3, 3 x F4, 1 x F5, 3 x F6, 3 x F7). It transpired that identification of the scene was possible because these students had either visited the area or had seen other photographs. Occasionally an experience of a a more personal nature became evident.

> I "What have you heard about it (Milford Sound) - if anything?"
>
> L "Dad's been down there on his boat."
>
> I "On his boat?"
>
> L "Yes - he's a trawler skipper (302)

In one instance the scene was recognised and then confused with another area of the South Island.

> I "Tell me about Milford Sound - what do you know about Milford Sound?"
>
> D "Oh - it's just where the ferries from the North Island to the South Island go." (503)

Twenty three students (4 x F1, 5 x F2, 4 x F3, 2 x F4, 3 x F5, 3 x F6, 2 x F7) stated that they had heard of Milford Sound, once the landform had been identified by name for them. Failure to recognise Milford Sound may have resulted, in some cases, from the photograph having been taken from a particular vantage point. Some students may have been exposed to views of Milford Sound and Mitre Peak that had been obtained from different locations.

Three students (2 x F1, 1 x F4) claimed that they had never heard of Milford Sound.

HOW DID MILFORD SOUND ORIGINATE?

Twenty students (4 x F1, 1 x F2, 4 x F3, 3 x F4, 4 x F5, 2 x F6, 2 x F7) were unable to offer any explanation as to how Milford Sound might have originated. The remaining seventeen students were prepared to offer a variety of theories.

Six students (1 x F1, 3 x F2, 1 x F3, 1 x F6) felt that Milford Sound has remained unchanged with time, having retained its present form since the Earth was formed.

> "They've (mountains and fiords) probably been there since the world started." (201)

Volcanic activity was offered as a possible mechanism of formation by five students (1 x F1, 1 x F2, 2 x F4, 1 x F7):

> I "How has that (Milford Sound) formed?"
>
> S "Probably been volcanoes." (402)
>
> "It (formation of Milford Sound) could be by old eruptions or old volcanoes or something." (701)

One student (1 x F7) made reference to "plate theory" as a contributing factor in the development of Milford Sound. This idea was not enlarged upon.

> I "Have you any ideas on how that particular scene was formed?"
>
> C "Well - I'd have to say it's something to do with plate theory again, but it's not something I'm too sure about." (703)

Milford Sound was connected with past glaciation by five students (1 x F4, 3 x F6, 1 x F7). However, only three of these (1 x F4, 2 x F6) offered an explanation which included a glacier reaching the coast and extensively cutting down to produce a deep valley. The term 'fiord' was not used by these students.

> "It's (Milford Sound" caused by these glaciers cutting away at the terrain." (601)

WHAT IS THE NATURE OF THE WATER IN MILFORD SOUND?

Attention was focused on the water body in Milford Sound to ascertain whether, or not, students realised that the sound did open out to the sea.

Fourteen students (1 x F1, 2 x F2, 2 x F3, 3 x F4, 2 x F5, 3 x F6, 1 x F7) considered that the water was definitely sea water. However, the reasons underlying this assumption varied, as shown:

i) The Sound is a Natural Bay, Inlet or Estuary

Five students (1 x F2, 1 x F4, 1 x F5, 1 x F6, 1 x F7) saw Milford Sound as being either an inlet, natural bay or estuary, having no links with past glaciation.

> "It's an inlet of the sea." (502)

> "More of an estuary. You've got all your fresh water coming down from your mountains - mixing with all your sea water." (703)

ii) Seabirds Suggest Seawater

Two students (1 x F3, 1 x F5) did not indicate that they knew, for certain, that the body of water was from the sea. The presence of seagulls, on the photograph, indicated to them the possibility that they might be looking at part of the sea.

> I "This water here (points to photograph) - what do you think that is - sea or a river or a lake - or what?"
>
> S "Sea."
>
> I "What makes you think that?"
>
> S "Birds here. (Points to gulls on photograph). (301)

iii) Driftwood Suggests Seawater

One student (1 x F2) recognised the presence of driftwood, from the photograph, and this suggested that the body of water might well be an extension of the sea.

I "And the water there (points to photograph) - do you think that's a river or part of the sea or a lake or - what?"

L "It looks like part of the sea."

I "What makes you think that?"

L "Well - because the way - there's driftwood all over the beach and that." (201)

iv) The Size of the Water Body Suggests the Sea

The area of water, shown in the photograph, led one student (1 x F1) to suggest that it might be the sea.

M "I think that's sea."

I "Why do you think that?"

M "Because it's bigger than a river but it's not bigger than an ocean." (105)

v) Personal Experience

One student (1 x F3) had been to Milford Sound and this student's father had worked on a fishing boat which used the Sound as a base (see earlier quote in this respect).

I "This water here (points to photograph) - do you think that's a river or a lake or part of the sea - or ...?"

L "Sea." (302)

vi) Seen other 'Pictures' of Milford Sound

One student (1 x F4) had seen other pictures/photographs of Milford Sound. This past experience led to instant recognition of the landform.

S "It's Milford Sound."

I "Have you been there?"

S "No - I've seen it - I've seen pictures."

I "I see - can you tell me anything about Milford Sound?"

S "It has quite high mountains around and there's - the sea going around here (points to photograph) around it." (402)

vii) Glaciers Known to Have Reached the Sea at this Point in the Past

Three students (1 x F4, 2 x F6) were aware that past glaciation had contributed to the formation of Milford Sound and that a glacier had reached the sea at this point.

I "What do we see on the picture?"

D "A fiord."

I "A fiord - what's a fiord?"

D "Well, it's where the glacier has carved out the rock and that - and it's got sea-level - and the sea's come up into where it's been carved out." (401)

I "And how was that view (Milford Sound) arrived at - how did that landform develop?"

W "Glaciers again."

I "Tell me about that."

W "They've worn - they just keep on wearing below the sea - they wore it out anyhow. These V-bottomed valleys - no - U - flat - U-shaped valleys, sorry - and I guess either the sea was shallow or the mountains were - I think the sea would have been - at a time when the sea was at a lower level and they would have formed the mountains, like in the other picture, formed the valleys and then the sea's come back in again. They are quite deep, I know that." (603)

Nine students (1 x F1, 2 x F3, 1 x F4, 2 x F6, 3 x F7) considered the water body to be a lake. The reasons for this response fell into three categories.

i) A Complete Guess

Seven students (1 x F1, 2 x F3, 1 x F5, 1 x F6, 2 x F7) were unable to supply any information about Milford Sound, other than its approximate location. The presence of a lake was guessed at.

"It's a lake - with a few mountains in the background." (101)

R "It's just a lot of mountains - and quite a - umm - lot of water. Could be a lake or something." (604)

ii) High Rainfall Experienced

Two students (1 x F4, 1 x F5) had visited the Milford Sound area and had experienced heavy rainfall during their stay in the area. This may have led them to conclude that the water, shown on the photograph, represented a lake.

I "Tell me about Milford Sound."

M "I don't know much about it - it was raining when we went through there - we missed it - it was pouring down with rain and all the clouds were low."

I "The water here (points to photograph) - what sort of water do you think that would be - a freshwater lake or seawater or just a wide river or what - what do you think?"

M "Fresh water." (504)

The ideas of a crater lake was proposed by the following student.

I "Tell me about Milford Sound."

F "It's a whole lot of valleys which fill with water."

I "This water here (points to photograph) is that a river or a lake or part of the sea - or what?"

F "It could be a big lake."

I "And how has that formed - do you think?"

F "Well, it's wet country - a lot of rainfall - it's probably a crater - it's a bit like that." (403)

iii) A Glacial Lake

Two students (1 x F6, 1 x F7) were aware that glaciation had influenced the Milford Sound area in the past and, these same students, considered that the water, within the Sound, had been left there after a glacier had melted.

A "Well it (the glacier) would have retreated up both valleys."

I "To leave that lake there?"

A "Yes - it melted down." (605(g))

also

I "Well - just sort of looking at that photograph - the water there - any ideas on that - river, lake, sea - whatever?"

R "Glacier - it left the water - it could have melted and it couldn't get out because of this land (points to photograph)." (704(G))

Four students (2 x F1, 1 x F2, 1 x F5) were inclined towards the idea that the water, shown in the photograph, represented a river. These students did not possess any knowledge concerning the evolution of Milford Sound and their consideration of a river was based upon a visual inspection of the photograph.

"I can see a big hill on both sides of the river." (104)

"It's a wide river - I think." (501)

Three students (1 x F1, 1 x F2, 1 x F7) were not able to identify the body of water and made the following estimates.

"A lake or river." (103, 203)

A lake or the sea." (701)

STUDENTS' MEANING OF THE WORD 'FIORD'

The word 'fiord' was presented on a card, to each student at the end of their interview. This exercise enabled the investigator to establish whether, or not, students held scientifically acceptable ideas about a fiord and also indicated some of the more idiosyncratic views that might be associated with the term. Furthermore, the use of such a stimulus-word might lead to students recalling other items of information, concerning glaciers and the evolution of Milford Sound.

Seventeen students (5 x F1, 4 x F2, 2 x F3, 2 x F4, 2 x F5, 1 x F6, 1 x F7) stated that they had not heard of the word 'fiord' and they were not prepared to speculate as to its meaning.

Seven students (1 x F1, 1 x F3, 2 x F4, 2 x F5, 1 x F6) thought that a fiord was an inlet that allowed the sea to come inland. The idea of the sea 'eating away' at the land was mentioned as one mode of fiord formation.

D "There's a lot of mountains and they've got inlets in them - and you have them in Switzerland and places like that - Norway ..."

I "Do we have them (fiords) in New Zealand - do you think?"

D "I don't think so - no, I don't think there are any of them here."

I "How do you think these inlets are formed - any ideas - or have they always been there?"

D "Well the sea could have eaten away at the land and finally found its way in." (305)

The idea of hiding ships in fiords, during "the war" was mentioned.

"That's (fiord) an inlet of water what they have in Sweden mainly - and they used them a lot during the war for hiding ships." (602)

Other idiosyncratic ideas, concerning the nature of a fiord, were expressed.

> "Where steep rocks go into deep water." (703)
>
> "A bay." (204)
>
> "A stream." (702)
>
> "Hills with water in between them." (403)
>
> "Swampy country." (302)
>
> "Wat r in between mountains." (604)

Two students (1 x F3, 1 x F7) confused the term 'fiord' with the word 'ford', i.e. a shallow place where a river may be crossed by wading or driving through it!

> "Is that where a river goe across the road?" (301)
>
> "All it means to me is s ething that a car goes through." (705(g))

Five students (1 x F4, 3 x [illegible] x F7) were able to explain the term 'fiord' and link it with the [illegible] ses of glaciation.

> "It's (fiord) where the glacier - umm - carved out - carved its way down the mountainside and the glaciers reached down to sea level and the sea's come in. It happens over millions of years." (401)
>
> "Yes, they are sounds - fiords and sounds are much the same - formed by glaciers. Yes, they are deep valleys where the sea's come in over them again." (603)

LEARNERS' VIEWS COMPARED WITH SCIENTISTS' VIEWS

Results from this investigation, indicate that the majority of students have at least heard of glaciers and their ability to move. Very few students had actually seen a glacier and, it might be expected, that an aerial view of a glacier will not be readily identified by students who have not witnessed glaciers first-hand from such a vantage point.

Most learners were aware that glaciers are large bodies of ice yet the often considerable depth of ice and the erosional importance of glaciers was largely unappreciated.

A comparison between the learners' views of aspects of glaciation, and those held by scientists, are summarised in Table I.

LEARNERS' VIEWS CONTRASTED WITH SCIENTISTS' VIEWS

	SCIENTISTS' VIEWS	LEARNERS' VIEWS	IDIOSYNCRATIC VIEWS
WHAT IS A GLACIER?	A body of ice capable of flowing over a land surface	Majority view close to scientists' view	i) Frozen river ii) Moving rock with ice on top
DOES A GLACIER MOVE?	Ice accumulates at head of glacier and gravitational force assists ice body in moving down slope.	i) Glacier seen to move (70%) ii) Action much like a river flowing downhill	i) No movement seen ii) Rock moves and carries ice along iii) Snow falls directly on glacier - causes growth of glacier iv) Movement controlled by air temperature
HOW DEEP IS GLACIAL ICE?	Glaciers contain great volumes of ice with depths of several hundred metres not uncommon	i) Depth largely unknown (54%) ii) Glacial ice is relatively thin	i) Few millimetres
WHAT IS MORAINE?	Rock debris transported by glaciers and re-deposited	Moraine largely unknown (84%)	i) Landslide deposit
WHAT IS A CREVASSE?	A deep crack in the upper surface of a glacier	i) Term unknown by 38% of students ii) Hole or gap - not associated with glacier (30%) iii) Cracks in glacier (30%)	i) Part of a volcano

Table 1

Only a minority of students, who contributed to this investigation, realised that Milford Sound represents the end-product of past glacial erosion. It would appear that fiord evolution and glacial activity were not seen to be linked by a cause-effect mechanism.

The views that are held by children and adolescents, from this investigation, concerning Milford Sound, are shown in Table 2. These views are compared with the views that are likely to be held by scientists.

LEARNERS' VIEWS CONTRASTED WITH SCIENTISTS' VIEWS

	SCIENTISTS' VIEWS	LEARNERS' VIEWS	IDIOSYNCRATIC VIEWS
HOW DID MILFORD SOUND ORIGINATE?	Glacier eroded an existing valley below sea level	i) no ideas (54%) ii) Always there iii) Volcanic origin iv) Some connection with glaciation (14%)	i) Something to do with 'plate theory'
WHAT IS A FIORD?	A glaciated trough submerged by sea	i) No ideas (46%) ii) Inlet which allows sea to enter land iii) Similar to scientists' views (14%)	i) River crossing ii) Swamp country

Table 2

SUMMARY

The responses, obtained during the described interviews, tend to suggest that the majority of these students do realise that glaciers are bodies of ice which have a tendency to move. However it would appear that, in general, these children and adolescents do not place glaciers within a perspective of fluctuating climate. Furthermore, there has been little evidence, from this investigation, to indicate that learners are aware of the major erosional properties, normally associated with glaciers.

It is apparent that this lack of appreciation of the erosive powers of glaciers has resulted in students not being able to link glacial activity with the evolution of fiords and U-shaped valleys which exist today, in those regions where glaciers were once active.

APPENDIX A

Earth Science

SECTION 4

AIM: To introduce students to the variety of landforms, rocks and soils; and through an investigation of their formation emphasise their changing nature. To involve students in outdoor observations and in a variety of communicative skills.

After completing this section, a student should be able to:

Content

1 a Identify the major landforms in his local area.

b Explain how these landforms may have been formed.

c Describe the agencies of change acting on these landforms including not only such agencies as volcanism, earthquake, water, wind, ice, etc., but also Man and his machinery.

d Explain the three major ways in which rocks are formed.

e Describe how different rock types give rise to different kinds of soil.

f Discuss how differences in landforms, rocks and soils influence Man's use of an area.

Skills

2 a Read simple geological and topographical maps of the local area.

b Classify rocks in various ways, e.g. structure, hardness, colour.

c Observe and describe the characteristics of local rocks and soils using a hand lens.

d Dig a soil profile and infer how the layers may have been formed.

Attitudes

3 a Appreciate the changing nature of the earth's surface and the importance of conservation practices.

b Show a willingness to expand their knowledge and interest in landforms, rocks and soils by continuing their personal observations investigations and reading.

AIM: To extend the knowledge of landforms gained at level 4 by considering the earth's crust, the layered structure of the earth, its atmosphere, the dynamic nature of the surface layers and the geological history of New Zealand.

After completing this section, a student should be able to:

Content

1 a Describe the plate theory of the earth's surface and discuss the evidence supporting such a theory.

b Relate the plate theory to earthquakes, mountain building, volcanic zones and major fault lines.

c Describe the theory of continental drift and discuss the evidence supporting such a theory.

d Define a fossil and describe ways in which fossils may be formed.

e Outline the major features of New Zealand's geological history.

f Describe the formation of fossil fuels and discuss the importance of their conservation.

g Define a mineral and discuss Man's use of minerals in New Zealand.

Skills

2 a Produce charts, displays, models or other descriptions of the structure of the earth's crust, its dynamic nature or the geological history of New Zealand.

b Group fossils, minerals and major rock types according to characteristic features.

Attitudes

3 a Display a continuing interest in earth science, in Man's increasing knowledge of the nature of history of the earth's crust particularly in the South Pacific and in Man's use and conservation of his environment.

APPENDIX B

GLOSSARY OF TERMS

CARBONIFEROUS: That period of geologic time which extended, approximately, from 340 million years to 280 million years B.P.

CIRQUE: A steep-walled niche with the form of a half-bowl. Cirques are located in mountainsides and are developed by the action of frost wedging and glacial plucking.

CREVASSE: A deep crack, located in the upper surface of a glacier.

EROSION: The process of removal of weathered material from one site to another.

FIORD: A glaciated trough which has become partly submerged by the sea.

GLACIATION: The change of land surface by means of the movement of glacier ice.

GLACIER: A body of ice which comprises recrystallised snow which is able to flow over a land surface.

ICE AGE: A period of geologic time during which glaciations reach a peak.

ICE SHEET: A mass of ice which covers a large area of land and sea, to a considerable depth.

INTERGLACIAL: The period of time between successive glacial advances.

LATERAL MORAINE A ridge formed by moraine which has been deposited at the side of a valley glacier.

MEDIAL MORAINE Moraine which is transported on the middle section of a glacier. Such moraine is formed by the coalescing of adjacent lateral moraines, when two valley glaciers merge.

MORAINE Weathered rock debris that is transported by glacial action and deposited at a new site.

NÉVÉ The area of perennial snow at the head of a glacier.

PERIGLACIAL The conditions and processes which exist at the margins of glaciers and ice sheets.

PIEDMONT GLACIER	A glacier found at the base of a mountain and 'fed' by at least one valley glacier.
PRECAMBRIAN	That period of geologic time which extended, beyond 600 million years B.P.
QUATERNARY	That period of geologic time which extended, approximately, from two million years B.P. to the present.
TERMINAL FACE	The lower margin, or snout, of a glacier.
VALLEY GLACIER	A glacier that flows downward through a valley.
WATERSHED	A drainage basin.
WEATHERING	The breakdown of rock material by physical, chemical and biological action.

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