A GUIDE TO SOME LOCALITIES OF GEOLOGICAL

AND PALEONTOLOGICAL SIGNIFICANCE

IN NEW SOUTH WALES AND NEW ZEALAND

Prepared for the South Pacific Division
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(*Adapted from the original printed version*)

THE GEOLOGIC COLUMN

ERA	SYSTEM OR PERIOD	SERIES OR EPOCH	STANDARD TIME SCALE*
Cenozoic	Quaternary	Holocene (Recent)	0.001
		Pleistocene	2.5
	Tertiary — Neogene	Pliocene	7
		Miocene	26
	Tertiary — Paleogene	Oligocene	38
		Eocene	54
		Paleocene	65
Mesozoic	Cretaceous	Upper, Lower	136
	Jurassic	Upper, Middle, Lower	190
	Triassic	Upper, Middle, Lower	225
Paleozoic	Permian		280
	Carboniferous		
	Pennsylvanian	Upper, Middle, Lower	325
	Mississippian	Upper, Lower	345
	Devonian	Upper, Middle, Lower	395
	Silurian	Upper, Middle, Lower	430
	Ordovician	Upper, Middle, Lower	500
	Cambrian	Upper, Middle, Lower	570
Precambrian		Upper, Middle, Lower	4600

*Represents millions of years; not endorsed by the Geoscience Research institute

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INTRODUCTION

This guide highlights briefly the main localities that will be visited by the Geoscience Field Conferences. The brief descriptions are intended to provide some reference material for field localities. Localities were selected on the basis of accessibility, general geological and paleontological significance, and, especially, of significance to conflicting scientific and biblical interpretations of the past history of the earth.

An attempt (with admitted failure) has been made to simplify the material so that individuals without paleontological or geological training might gain some understanding of the significance of the issues being discussed. For those desiring to pursue the questions further, some important references have been provided.

Significant to the past history of this Earth is the standard geologic column, which gives relative position and time to the interpretations of the various localities. A simplified version is provided for convenience. The times given in Ma (millions of years) are not endorsed by the writer.

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BRIEF COMMENTS ON THE GEOLOGY OF AUSTRALIA

General Features

Australia has a geologic past that is sometimes characterized as being different from that of the rest of the world. Some differences do exist; yet in many aspects it is quite similar. This fascinating continent is both the flattest and most arid of the continents. It also claims evidence of the oldest rocks (Froude et al. 1983) and the oldest life (Schopf & Packer 1987, Buick 1990).

Mountain ranges are the exception in Australia, and 94% of the continent is less than 610-m high. The highest mountain, Mt Kosciusko, in the SE, is only 2228-m high; however, the winter "snowfields" of Mt Kosciusko are reported to be larger than those of all of Switzerland.

In terms of physiography and geology, Australia can be divided into three main regions. On the W are the flat Precambrian shield areas; along the E coast is a fold mountain belt running from N to S, forming the Great Dividing Range. Between these E and W portions is the large central plain which occasionally will dip below sea level (e.g., Lake Eyre, -14 m). This central plain harbors a number of interior drainage basins which have no outlet to the seas. The geology of these regions is complex, with some Precambrian dominating the W region, while Paleozoic and Mesozoic rocks dominate the central and E region. Major portions, especially in the central region, are covered by a blanket of Cainozoic (Cenozoic) deposits. Australia's most notorious geologic feature — Ayers Rock — is an isolated Cambrian (?) deposit penetrating through this blanket.

The geologic history of Australia is interpreted as a complex of a number of cycles involving major sedimentary depositional events followed by uplift and erosion. A number of marine invasional episodes are postulated, including a major Lower Cretaceous event which covered most of the continent. Mountain-building and volcanic episodes are distributed throughout the geologic history; however, Australia does not have a major recent mountain-building episode as is found in New Zealand and on other major continents. Evidences of glaciation are found in the Precambrian and Carboniferous, as well as some recent activity reported in SE Australia, including major glacial erosion in Tasmania. Coal is fairly abundant in central-E Australia (Wells 1983), with a little on the W and N coasts. It is dominantly in Permian, Jurassic and Cretaceous deposits. Fossil evidence suggests a wetter climate in the past for many parts — including the arid central portion — of Australia. Various changes in the position of the Australian continent are postulated in the context of the plate-tectonics model. It is now assumed that Australia was closely associated with Antarctica and other Gondwanaland continents in the Mesozoic, having since separated and moved to its present position. Further general information on the geology of Australia can be found in Brown, Campbell & Crook (1968), Brunnschweiler (1984), Palfreyman (1984), and Veevers (1984).

Sydney Basin

The Australian field localities described below will be introduced by brief comments about the Sydney Basin, with which they are associated. The Sydney Basin is an elongated area of sediment deposition approximately 100-km wide and extending about 200 km both N and S of Sydney.

As a distinct sedimentary entity, the Basin is a small Permian latecomer superimposed on the Tasman Geosyncline — a broad area of Paleozoic sediments along the E side of Australia. Uplifted fold belts formed on either side, delineating the present Sydney Basin. To the W the Basin is limited by the Lachlan Fold Belt in the Great Dividing Range, while to the NE it is limited by the New England Fold Belt which lies E of a line extending from Newcastle to Tamworth. The Sydney Basin extends N into the Gunnedah Basin and even further into the Bowen Basin in Queensland. The whole complex forms the Sydney-Bowen Basin (Herbert & Helby 1980, pp. 3-4). To the SE the Sydney Basin extends offshore to the edge of the continental shelf beneath the Tasman Sea (Mayne et al. 1974).

The sedimentary deposits of the Sydney Basin reach up to 6 km in thickness. In the lower parts they consist of alternating marine and non-marine Permian rocks which include volcanic rocks and coal, along with high-energy conglomerate deposition. These sediments are overlain by mainly non-marine Triassic formations. Some of the more important units are outlined below in descending order of occurrence (Herbert & Helby 1980, p. 22).

GEOLOGIC PERIOD

- Triassic
  - Wianamatta Group
  - Hawkesbury Sandstone
  - Narrabeen Group
  - Gosford Sub-Group
  - Clifton Sub-Group
- Permian
  - Newcastle Coal Measures - Illawarra Coal Measures
  - Tomago Coal Measures
  - Berry Siltstone
  - Nowra Sandstone
  - Branxton Formation
  - Greta Coal Measures
- Carboniferous
  - Seaham Formation

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SWANSEA HEADS - NEWCASTLE COAL MEASURES WITH UPRIGHT TREES

Location

Swansea Heads is located about 3 km E of the town of Swansea. In Swansea Heads go to the N end of town and park by the signal station. Walk E, then S along the shoreline to view the coal seams in the tidal area at the foot of the cliff below the signal station.

Stratigraphic Position

The exposed Pilot Coal seams are in the Boolaroo Subgroup of the Late Permian Newcastle Coal Measures.

Description

Note the beds dipping about 8° to the W. The Lower and Upper Pilot Coal seams are found at tide level and in the cliff to the W. Some of the coal is replaced by chalcedony (a form of quartz with microscopic-sized crystals). Note the contact between the seams and the underlying and overlying rock layers.

The most striking feature of this locality is the presence of upright tree stumps on top of the Lower Pilot Coal. The trees are preserved in the overlying tuff and may have been partially burnt by an ashfall and/or coalified subsequently. Herbert & Helby (1980, p. 465) refer to an old report of vertical stumps in the vicinity protruding up to 10 m into the overlying tuff. These authors believe the tree stumps to be *in situ.* Fritz (1980) and Coffin (1987) give evidence that trees can float upright in mud and under subaqueous conditions.

Also noteworthy at this locality are: 1) a number of prostrate fossil logs especially abundant at the foot of the cliff to the S, 2) smaller fossil organic debris, and 3) the interesting phenomenon of boxwork where the sediments are boxed in by more resistant layers formed along cracks (covered with sand in 1992).

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MEREWETHER BATHS - NEWCASTLE COAL

Location

Merewether Baths is located along the coast SE of the town of Merewether, which is just S of Newcastle. To reach the coal seams, walk S from the parking area by the bath facilities to the foot of the high cliff on the W.

Stratigraphic Position

This is part of the Lambton Subgroup of the Late Permian Newcastle Coal Measures.

Description

Three main coal measures can be noted in the cliff to the W. In ascending order from the foot of the cliff they are: the Dudley Coal, the Nobbys Coal, and the Victoria Tunnel Coal. Between the Nobbys Coal and the Victoria Tunnel Coal is the grey Nobbys Tuff Member which forms a vertical cliff with a strong parallel bedding pattern. A normal fault with a few meters displacement down to the S is easily observed. The top of the cliff is capped by the Merewether Conglomerate. Generally it is agreed that these coal seams were deposited over long periods of time in deltas, meandering river, lake, and swamp environments (e.g., Warbrooke 1987).

A good view of the Nobbys Coal just S of the fault shows several good clastic partings within the coal seam. The parallel arrangement of the coal and the partings within the seam suggest an allochthonous (transported) origin. Coal seam splitting in these seams has been interpreted by Warbrooke & Roach (1986) as due to flooding (a model that fits well with the Genesis flood) or tectonic (uplift and subsidence) factors controlling the distribution of sediments.

The environment proposed for the Newcastle Coal Measures includes a variety of unrelated climatic conditions. Loughnan (1966) outlines these:

> *... (a) a frigid to cold-temperature, humid climate based upon the ideal conditions for the preservation of peat and upon the occurrence of possible glacial or ice-rafted erratics; (b) a hot, humid or periodically humid climate based on the possible derivation of the kaolinitic claystones from highly leached soils; and (c), a warm to hot semiarid climate based upon the formation of the analcite in playa lakes. However, these proposals need not be as irreconcilable as they appear.*

Important to the question of time in the fossil record is the interpretation of the mode of origin of the coal. If the vegetation producing the coal grew *in situ* (autochthonous origin), considerable time would be involved in producing the many seams of the Newcastle Coal Measures. On the other hand, if the seams represent transported vegetation (allochthonous origin), a long period of time might not be mandated. Points favoring an autochthonous origin (see Duff 1967 for discussion) are: 1) upright trees above the coal seams, and 2) some vertically oriented roots (*Vertebraria*) below coal seams. Points favoring an allochthonous origin are: 1) absence of the "seat-earth" common in Carboniferous American and European seams, 2) absence of vertical roots and rootlets on the glossopterid trees, and 3) the presence of extensive conglomerates 260 km, suggesting catastrophic conditions. Furthermore, the very parallel seams and partings do not indicate in-growth conditions of trees. The following quotation from Duff (1967) lists some factors in the controversy:

> *Booker (1960, pp. 30-31), on the other hand, was unhappy with the 'drift' theory and voiced some of the obvious and valid objections. What catastrophes would be required to produce for transportation the millions of trees necessary to produce one coal seam? What conceivable sedimentary mechanism could so sort out debris that only trees would be transported to a particular site in a basin of deposition, there to conveniently sink?*

A worldwide flood could answer some of Booker's objections, such as a significant source for the vegetation (millions of trees) and possible sorting of trees and sediment by density factors. Such a flood could also transport from different sources some of the minerals that are the basis for the conflicting climatic data indicated in the quotation by Loughnan (1966) given above.

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SEAHAM "GLACIAL VARVES"

Location

The varves are well displayed at the Seaham Quarry just S of the main part of the settlement of Seaham. As you go S towards Raymond Terrace, turn to the right (W) on Cross Street. The Quarry is at the left. Another good exposure can be found further S along the road to Raymond Terrace just S of the intersection with Cross Street in a roadcut to the right (W).

Stratigraphic Position

The varves are found as groups in the Seaham Formation which is Late Carboniferous-Early Permian (Benson 1981).

Description

The Seaham Formation, which is approximately 530-m thick at Seaham, contains 3 sets of varves (sedimentary layers interpreted as annual cyclic lake deposits). In this formation they vary in thickness from 0.05 to 20 cm. The rest of the formation consists of mudstone, tillite (consolidated unsorted glacial deposits), tuffs, and fluvo- glacial conglomerates (Sussmilch & David 1920). The varves have been most famous for their good preservation and contorted beds. The main layers consist of clay and shale, while minor layers between consist of fine sandstone which may be graded and/or cross-laminated. Occasionally granitic dropstones (pebbles dropped from floating, melting ice blocks above) up to 6 cm in diameter are found within the layers. These and the tillite found in the vicinity constitute some of the strongest evidence for glaciation in this region. In the Maitland area, Osborne & Browne (1921) described 2 small patches of rock "not above six square feet in each exposure" that showed evidence of being smoothed, grooved and striated, as can be produced by the flow of rock-laden ice.

By counting pairs of layers as a single varve (annual deposit), Sussmilch & David (1920) estimated that it would take about 3000 yr to deposit the varves of the Seaham district. Osborne (1925) questioned the reliability of the annual interpretation. Other workers "have been more cautious about the use of the term 'varves' in reference to the Seaham strata" (Percival 1985, p. 98). Turbidites are considered to be a definite possibility (Crowell & Frakes 1971, Rattigan 1967). Engel (1980) proposed a different origin, suggesting that "it is possible that many of the so-called varves are delicately graded volcanic ash deposits."

The origin of the contortions of the layers has also been a subject of controversy. It was originally thought to be due to disturbance by ice or icebergs. However, after considering various possibilities, Fairbridge (1947) concluded that most was caused by gravitational slumping, probably from the periodic release of water from the lake in which the layers had accumulated. Since many layers are involved in a single contortion, the layers were probably soft, and one layer was not hard before the next was laid down.

A further problem exists with the question of climate. Both Loughnan (1975) and Benson (1981) point out the evidence for a humid subtropical climate in the region which is at variance with glacial conditions that are expected for the Seaham Formation. Their evidence includes thick coal deposits, kaolinite clayrocks N of Wingen (Loughnan 1975) and bauxite and laterite tropical type of soils found in E New South Wales (Benson 1981). On the other hand, Benson also points out that the pulverized feldspar of the varves of the Seaham Formation could not have survived at this grain size in a hot humid climate. He suggests 2 periods of subtropical climate between glacial maxima, although he agrees that this is enigmatic. Stutchbury (1989) proposes a cold but catastrophic environment for the Early Permian Pebbley Beach Formation S of Sydney. His evidence includes drop- stones.

The presence of such glacial activity in the middle of the geologic column poses problems for a flood model of earth history. It is difficult, though not impossible, to conceive of glacial activity during a worldwide flood. Furthermore, standard interpretations of glacial activity envision considerable time. The problem of glacial action is not limited to this region. It is generally agreed that there is convincing evidence of glacial activity during the Late Paleozoic over much of the S half of Australia. Some of the striated pavement found in South Australia (Bourman, Maud & Milnes 1976) appears quite similar to that seen for recent glacial activity. Varves, tillite, and striated pavements of Paleozoic glaciation have been described in Africa and South America. Precambrian glaciation is also described in Australia (Link & Gostin 1981; Hambrey & Harland 1981, pp. 502-557).

On the other hand, one must also recognize that the identification of past glacial activity is difficult and has sometimes been the subject of disagreements. The classical evidences of glaciation can be confused with other more rapid phenomena. For instance, glacial striations can be confused with slickensides caused by slippage at a fault; scratches on small rocks can be caused by transport in a debris flow; varves can be turbidites; and tillite can be confused with a debris flow.

The scientific literature reports several examples of glacial activity from many parts of the world that have been reinterpreted as probably due to other factors. Some revised interpretations include: slickensides in Argentina (Dunbar 1940), submarine slides in Mexico (Newell 1957), submarine mudflow in Angola (Schermerhorn 1974), logging cable marks in the United States (McKeon et al. 1974), mudflows in India (Lakshmanan 1969), subaqueous mass movement in the United States (Dott 1961), turbidity current or subaqueous mudflows in France (Winterer 1964), Permian sediments in Scotland (Schwarzbach 1963), slickensides in Sweden, subaqueous mudflow in Norway, turbidity current and volcanic mudflow, and turbidites in Canada (Crowell 1964). This list reflects the difficulty in identifying ancient glaciation. Jago (1974) has summarized some of the problems:

> *However, what is unequivocal evidence of glacial origin of a particular rock unit to one worker, may not be so to another. Furthermore, once a rock unit is formally named ('Woop-Woop Tillite') and portrayed on a map, the name is here to stay even if it is later shown that the 'Woop-Woop Tillite' is not of glacial origin.*

In terms of glaciation in general, there is little question regarding the authenticity of the glaciation found at the top of the geologic column (Pleistocene glaciation). Flood geologists attribute this to events immediately after the flood, but caused by the flood. Oard (1990) has proposed a model when climatic factors would bring on an ice age with subsequent melting in a few centuries. The main cooling factor is the occlusion of radiant energy from the sun by volcanic dust generated during the flood.

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BURNING MOUNTAIN

Location

Burning Mountain (Mount Wingen) is located N of the town Wingen on New England Highway 15. Proceed 5 km N of town to a parking area E of the highway. A 2-km walking track to the E and S will lead to the burning area. This is private property and should be treated with respect.

Stratigraphic Position

The first part of the trail is in the Upper Permian Bickham Formation, which overlies the Lower Permian Koogah Formation in which the main part of Burning Mountain is located (Percival 1985, p. 94). The Koogah Formation is correlated with the Greta Coal Seams of the Lower Hunter Valley.

Description

Burning Mountain derives its name from a coal seam that is slowly burning underground. Aboriginal tribes are reported to have kept clear of the area (England 1982, p. 43), and the time and origin of the fire are unknown. An exposed part of the seam could have been struck by lightning or ignited from a bushfire. Most likely the coal, which contains a relatively high proportion of iron sulfide, could have ignited spontaneously. Around the turn of the century the fire was estimated to be about 50 m below the surface. Some suggest that the fire is progressing to the SW at the rate of about 1 m/yr. Identifiable by its reddish soil, slips and cracks, the burnt area extends to the NE for approximately 6.5 km and is crossed by the trail up the mountain. A journal in Sydney has erroneously referred to this mountain as a volcano.

Associated with the burning are many fissures and step faults caused by subsidence of the overburden from the burning of the coal. Intake of air through the fissures may produce a "blast furnace effect" (Rattigan 1967b). Sometimes the fire's quiet roar can be heard from the surface. Temperatures have been estimated as high as 1700° C, and some fusion of rock has taken place.

The hydrous fumes emanating from the fissures produce a sinter encrustation of quartz, hematite, and abundant sulphur (Rattigan 1967b). The iron of the black-red hematite is assumed to come from surface lateritic soil (Rattigan 1967a).

Burning Mountain raises questions about the statements of E. G. White regarding fire and volcanoes. Speaking of the flood she states:

> *At this time immense forests were buried. These have since been changed to coal\ forming the extensive coal beds that now exist, and also yielding large quantities of oil. The coal and oil frequently ignite and burn beneath the surface of the earth. Thus rocks are heated, limestone is burned, and iron ore melted. The action of the water upon the lime adds fury to the intense heat, and causes earthquakes, volcanoes, and fiery issues. As the fire and water come in contact with ledges of rock and ore, there are heavy explosions underground, which sound like muffled thunder. The air is hot and suffocating. Volcanic eruptions follow; and these often failing to give sufficient vent to the heated elements, the earth itself is convulsed, the*

ground heaves and swells like the waves of the sea, great fissures appear, and sometimes cities, villages, and burning mountains are swallowed up (PP 108-109).

Related statements are found in 3SG 79-80; MS 29, 1885; and MS 21, 1902.

Some have argued that White's statements reflect the thinking of her contemporaries. Although the idea of fire in the earth was temporarily accepted (e.g., Werner) before her time, she did not accept other contemporary geological concepts. She took a firm stand against uniformitarianism and in favor of the Genesis flood. Her statement about fires, coal, lime, and iron is considered to be "unique" (Johns 1977a).

That there have been many fires in the earth is well attested. Burning Mountain is only one example. Fires from burned coal seams as evidenced by a characteristic red imprint of the adjacent rocks are common in the western United States. Sometimes the glassy slag-type clinker attests to temperatures causing the melting of the rock. In Germany, fires burning for 150 yr are reported; one was used as a source of heat for a greenhouse for 31 yr (see Johns 1977b for references). Cisowski & Fuller (1987) refer to layers of burned rocks from depths of several hundred meters.

The question of a source of oxygen for burning is important. White refers to the hot air associated with these activities, and coal is known to be quite permeable to air (Johns 1977b). Some could come from iron oxide.

The main question would seem to be about the amount of heat required for the production of volcanoes as implied in PP 108. White's statements that coal and oil come from the flood (PP 108) and that there were volcanoes during the flood (MS 62, 1886) would suggest that she did not think all volcanoes came from the burning of coal. At present we do not know of good evidence for the burning of coal as the cause for volcanoes. Several plausible alternatives have been proposed.

1. This process of volcanism is not occurring now, although it did in a limited way in the past.
2. The burning of coal serves as a triggering mechanism to release other pent-up forces in the earth that would be the main driving force of volcanic activity.
3. God in His own time causes these special phenomena. The pertinent White account in 3SG 79 states, "God causes large quantities of coal and oil to ignite and burn." The suggestion that God may be active in some geologic phenomena is not without biblical support, as evidenced by the flood (Genesis 7-9) or the earthquake at Christ's death (Matthew 27:51), etc.

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FOSSILS IN BRANXTON FORMATION

Location

From just W of Millfield, which is SW of Cessnock, take Mt View road to the NW. At about 1.5 km from the junction, you will find a low roadcut on both sides of the road which exposes fossils in the Branxton Formation.

Stratigraphic Position

The Branxton Formation is Late Permian.

Description

The Branxton Formation consists of 980 m of grey-brown sandstone and shale with a general fining (becoming finer as one goes up-section) through the Formation. At this locality you are in the lower part of the Formation which lies just above the Greta Coal Measures. Poorly sorted grains of rocks and rock fragments are sometimes common. Large erratic rocks up to 9 m in diameter are occasionally found. These are composed of granite, lavas, metamorphics and quartzite and are thought to be ice-rafted to the formation (McKellar 1969). The formation is considered to be marine in origin, being deposited by weak currents primarily from the N which spread the marine fossils among the finer sediments (Crowell & Frakes 1971). This complex Formation has been divided into other formations and/or subdivisions. In this lower part, fossils of marine bivalves and spiriferid (spiral brachidium) brachiopods are present (Herbert & Helby 1980, p. 479) and can be found at this locality. Look at the road banks on either side of the road, as well as in the road bed. These and other marine organisms are also found higher up in the Formation.

The presence of marine organisms here and in other sediments on the continents is not unusual. Approximately half or more of the sedimentary deposits on the continents of the world are derived from the oceans. While at present some marine deposits are accumulating along the continental shelves (Great Barrier Reef), such a large proportion of marine material on the continents of the world seems anomalous to our present Earth system where marine material accumulates mainly in the ocean. The presence of all this marine material on the continents is interpreted mainly as indicating that the continents were lower in the past. This concept fits in well with a model of the Genesis flood that postulates a sinking of the continents to bring on a worldwide flood.

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DISCONFORMITY AT CLIFTON

Location

Between Wollongong and Sydney, S of the Royal National Park, proceed N along the coastal Lawrence Hargrave Drive past Scarborough and the settlement of Clifton. Go about 0.5 km down the first hill past Clifton. Park on the left (only space available) just before the beginning of the steep rock cliff on the left. A path down to the Bulli Coal Seam and adit starts across the road NW of the parking area. The path is steep, and those who feel insecure should not attempt descent. Near the bottom a ladder will lead you to the level of the adits and seam which are to the N. Only one person should be on the ladder at one time.

Stratigraphic Position

The Bulli Coal Seam seen here is at the top of the Illawarra Coal Measures. It is Upper Permian and is overlain by the Narrabeen Group whose lower portion is also Upper Permian. According to Herbert & Helby (1980, p. 512) the transition between the Permian and Triassic occurs in the Scarborough Sandstone which forms the first slabsided cliff just above road level to the NW at the top of the path.

Description

As you descend, the softer sediments forming the upper part of the path are the Wombarra Claystones which might be marine, since some calcareous microfossils have been identified here (Herbert & Helby 1980, p. 511). The lower sandstone units in the region of the ladder form the Coal Cliff Sandstone which locally contains well-developed concretions. The Bulli Coal which lies below has a thin shaley layer at its top. Below the Bulli Coal are the shaley sandy units of the Upper Eckersley Formation.

The Bulli Coal can be seen for some distance in the cliff to the N. Its parallel bottom and top is impressive. Some roots have been reported in the bottom of the seam, and some erosion is reported in the top (Shibaoka & Bennett 1975).

The contact between the thin shaley layer above the coal (not present everywhere) and the massive Coal Cliff Sandstone just above represent a disconformity (a gap in deposition between parallel layers, sometimes called a paraconformity). According to standard interpretations, part of the geologic column — about 5 Ma — is missing (Pogson 1972). The flatness of the contact raises doubts about the occurrence of this lengthy time gap, because significant, irregular erosion of the coal seam and much more would be expected in 5 Ma. The average rate of erosion in the United States is 6.1 cm/1000 yr (Judson & Ritter 1964), which amounts to 300 m in 5 Ma. Flat erosion or little or no erosion of a coal seam for 5 Ma seems incredible. If one assumes that these layers were deposited rapidly during the Genesis flood, little time is mandated between the layers.

The above-described situation is not isolated. Such a disconformity is a "basin-wide hiatus" with probable "world-wide significance" (Herbert & Helby 1980, p. 511). Similar situations at other contacts and much longer assumed time intervals can be noted in many parts of the world.

The notable lack of erosional features at these disconformities (paraconformities) in the geologic column can raise questions about the validity of the geologic time scale (Fig. 1). Quotations by two geological authorities attest to the problem:

> *A puzzling characteristic of the erathem boundaries and of many other major biostratigraphic boundaries is the general lack of physical evidence of subaerial exposure. Traces of deep leaching scour, channeling and residual gravels tend to be lacking even where the underlying rocks are cherty limestones (Newell, 1967b). These boundaries are paraconformities* [disconformities] *that are usually identifiable only by paleontological evidence* (Newell 1984).
>
> *I was much influenced early in my career by the recognition that two thin coal seams in Venezuela, separated by a foot of grey clay and deposited in a coastal swamp, were respectively of Lower Palaeocene and Upper Eocene age. The outcrops were excellent but even the closest inspection failed to turn up the precise position of that 15 Myr gap* (van Andel 1981).

For further discussion of details of this fascinating question, consult the reference by Roth (1988).

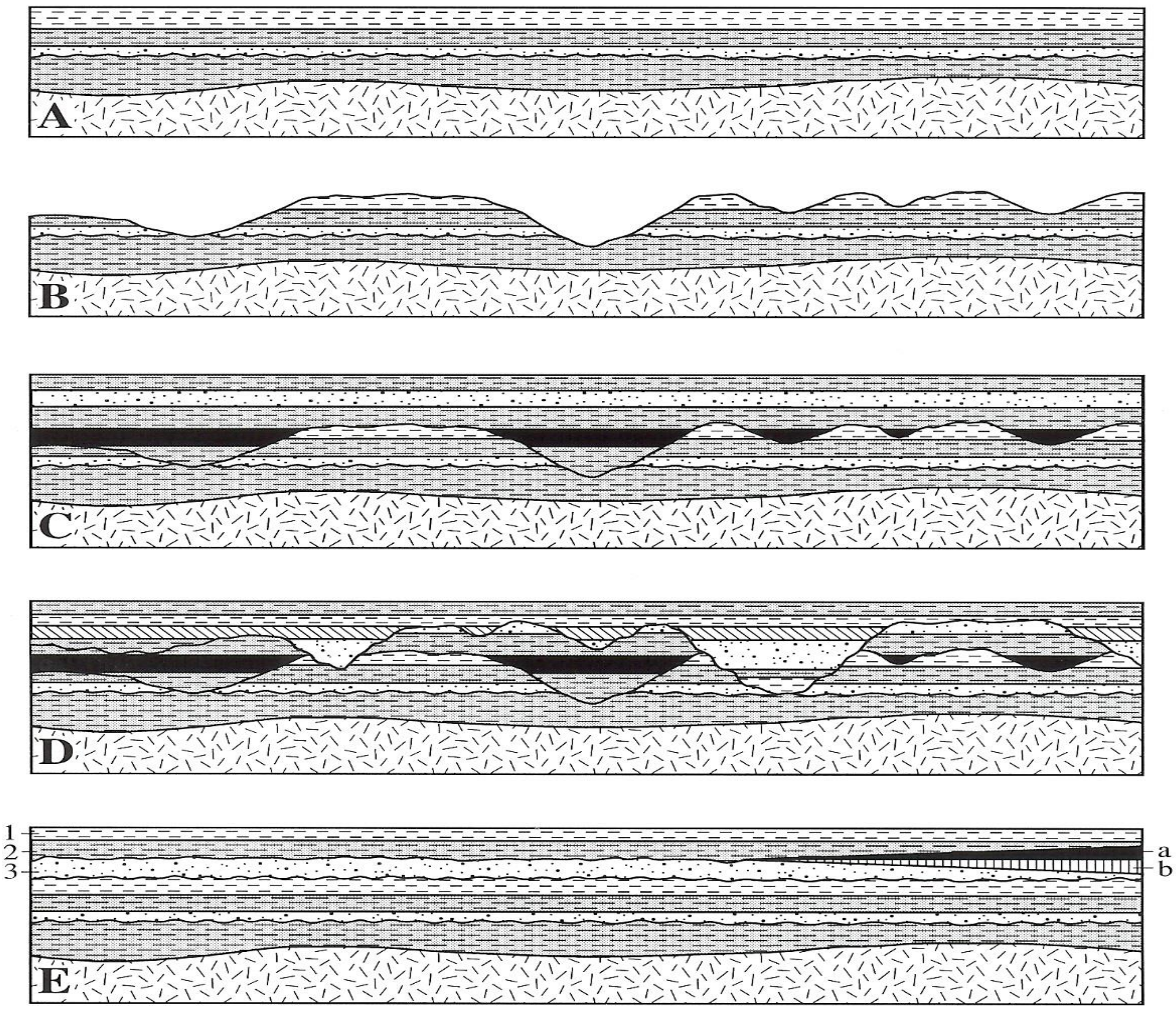

Figure 1. Erosion-deposition patterns. A: Pattern of continuous deposition. B: Erosion. C: Resumption of sedimentation. The old erosion surface is still visible. D: A second cycle of erosion and deposition further complicates the pattern. E: The more normal pattern seen. One would expect significant erosion between layers 2 and 3 from the top on the left side, if extensive time was involved in laying down layers 3 and 4 wedged in on the right. Hypothetical diagram with vertical exaggeration depending on erosional conditions.

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"WORM TUBES" AT THIRROUL

Location

The little town of Thirroul lies on the coast about 10 km N of Wollongong. Go to the N beach section and proceed S of the salt-water swimming pool past the pump house to the sedimentary strata forming the cliff below the dwellings on top of the cliff.

Stratigraphic Position

The lowest formation is part of the Erins Vale Formation, while the overlying strata are part of the Illawarra Coal Measures. All of these formations are Permian.

Description

Burrows ("worm tubes") in the Erins Vale Formation can be seen at beach level at the foot of the cliff below the dwellings to the W. A variety of burrows are present in the low, grey, cliff-forming units. Along the beach further S, more Erins Vale is identifiable, as well as the more colorful red-grey layers of the Wilton Formation which lie above. In the cliff to the W is the Woonona Coal, forming the lowest major coal seam of the Illawarra Coal Measures. The Wilton Formation forms the lowest of 7 cycles of deposition in the Sydney Subgroup (Illawarra Coal Measures). The Bulli Coal at Clifton (see previous location) is at the top of the uppermost cycle. Each cycle consists of a general fining of sedimentary units. Most cycles have a major coal seam at the top. The cycles have been interpreted as being caused by cyclic advances and retreats of the sea (Arditto 1987). Here the Wilton Formation begins with the reddish-grey sandstone with finer sedimentary units above and ends with the Woonona Coal which can be barely seen up the cliff below the dwellings. In Sydney, these same layers are 2800' below sea level.

It is suggested (Herbert & Helby 1980, p. 514; Bamberry, Hutton & Jones 1989) that the Erins Vale Formation was deposited in a shallow marine region with burrowing organisms living in the top portion producing the burrows. This was followed by a period of erosion (disconformity) before the deposition of the Wilton Formation which was a point bar (part of a meandering stream) environment. The Woonona Coal was deposited in a back swamp.

A degree of conjecture is involved in determining the paleoenvironments suggested above. Many appear unusually widespread. The most serious objection to the Genesis flood seems to be the burrows which would require some time for formation and which are quite common in a number of sedimentary strata. The burrow-producing organisms are rarely found. While some "burrows" have been attributed to such inorganic factors as escape of gas or fluids, some have the characteristic patterns of burrows built by living organisms and would not be expected in a catastrophe such as the Genesis flood. On the other hand, because burrows can be built quite rapidly, it is plausible that some were formed during the complex changes that would be expected during the year of the flood. Would organisms trapped in flood sediments try to burrow their way out, and during a lull in the flood events, would others establish burrows? Kranz (1974) reports rates of amphipod burrow formation up to 4.6 cm/hr for a 2-mm diameter burrow, and Howard & Elders (1970) noted rates of 1000 cm/hr for a 1.7-cm bivalve.

The top of the Erins Vale Formation is bioturbated, i.e., its sedimentary structure has been destroyed by biological activity. This process can also be quite rapid. On the ocean floor in the U.S. Virgin Islands, Clifton & Hunter (1973) have observed that organisms destroy sand ripples and laminations in the upper 2 cm in 2 – 4 weeks. If bioturbation in the ocean is so rapid, why are the bedding patterns of so many ancient marine limestones and shales still well preserved? If they represent slow deposition over millions of years, there should be ample time for all to be bioturbated. One must allow that unfavorable environmental conditions could reduce or prevent bioturbation.

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A BRIEF SYNOPSIS OF THE GEOLOGIC HISTORY OF NEW ZEALAND

The following description is the currently accepted view. It is based on careful study of interpretations deduced from contemporary paradigms. Further details are given in Lewis & Laird (1986), Suggate (1978), and Thornton (1985).

The geologic history is closely associated with plate tectonics. Up to the Late Cretaceous, New Zealand was intimately associated with the Gondwana supercontinent. It formed a marginal portion of this complex consisting of South America, Africa, India, Antarctica, and Australia, being closely associated with the latter two.

Here complex changes of deformation, sedimentation and erosion took place, followed by separation and more complex changes. These later changes were complicated by major right lateral movements of up to 480 km along the Alpine Fault and associated faults which run NE-SW along the length of New Zealand. This Alpine Fault is interpreted as the boundary line between two major tectonic plates. The Indo-Australian Plate lies to the NW, while the Pacific Plate lies to the SE.

The more detailed geologic history is usually divided into 3 pairs of episodes or cycles. These probably began with the Cambrian, assumed to be 570 Ma ago. Each cycle begins with a period of sedimentation, followed by uplift (orogeny) and the resultant erosion. Considerable overlap between cycles or parts thereof occurs in several instances. Different names have been applied by various authors to these 3 cycles. The following outline should facilitate understanding the terminology.

Event	Approximate Position in Geologic Column
Third Cycle	
Deposition - Kaikoura Sequence	Cretaceous to Recent
Orogeny - Kaikoura Orogeny	Oligocene to Recent
Second Cycle	
Deposition - Rangitata Sequence	Devonian to Cretaceous
Orogeny - Rangitata Orogeny	Triassic to Cretaceous
First Cycle	
Deposition - Tuhua (Buller) Sequence	Cambrian to Devonian
Orogeny - Tuhua Orogeny	Devonian

The Buller Sequence is found on the W coast of the South Island, mainly W of the Alpine Fault. It consists of some impressive sedimentary sequences several thousand meters thick. Its deposition was followed by the Tuhua Orogeny which involved uplift, folding, and granitic intrusion. The Rangitata Sequence of sediments is well represented throughout New Zealand and includes the E Torlesse Supergroup which consists of some 20,000 m of marine deposits with minor volcanic deposits. The Rangitata Orogeny involved both an early and later deformation and granitic emplacement. The Kaikoura Sequence, also well represented over New Zealand, often starts with coal deposits which are overlain by marine deposits. Small sedimentary basins are characteristic. The Kaikoura Orogeny began during the Oligocene and became very active in the Quaternary. This was accompanied by abundant recent volcanic activity especially on the North Island.

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GLOWWORMS OF WAITOMO CAVES

Location

Waitomo Caves are one of New Zealand's most famous attractions. The settlement of Waitomo is located on the Te Anga road as one goes W from Hangatiki which is approximately 60 km S of Hamilton.

Stratigraphic Position

Caves are in Oligocene deposits of marine limestone, sandstone, and siltstone.

Description

As you come to the Waitomo settlement, a conspicuous feature beyond the museum and open field is the Waipa Fault scarp (distal portion uplifted). Quaternary volcanic ash blankets the limestones, providing the source of some of the fine-grained sediment of the local streams (Pugsley 1984).

In the caves are a variety of speleothems. Their rate of formation varies according to several factors, e. g., water supply, mineral variety and concentration, rate of evaporation, partial pressure of gases in cave, etc.

The most famous features of the Waitomo Caves are the glowworms — the larval stages of the Dipteran fly *Arachnocampa luminosa.* The total life cycle takes 10-11 months (Gould 1986). The eggs hatch to produce 3-5 mm larvae which, after going through 5 instars (Pugsley 1984), measure 3040 mm. After a 2-wk pupation period, the adults emerge to live for only 3-4 days. The adults (12-16 mm) have no mouths and do not feed; they only mate, and the females lay up to 300 eggs. The dominant stage of the life cycle is the larval stage — the “glowworm" stage. The glow is produced at the rear end of the larvae at the tips of 4 excretory (malphigian) tubules. Glow comes from the action of the enzyme luciferase which is stimulated by the addition of ATP (Shimomura, Johnson & Haneda 1966; Lee 1976).

The larval stages build a tube-like nest of fine silk threads attached to the roof and walls of the cave. From this nest, as many as 70 "fishing lines", which extend up to 30 cm in length, are suspended. These lines are provided with sticky droplets to trap any insects that are flying toward the glow of the larva. Once an insect is trapped, the fishing line is pulled up, and the meal is eaten. Occasionally adult stages of the "glowworm" are trapped in the fishing lines (cannibalism); however, most of the food supply comes from small aquatic insects from the Waitomo stream that emerge within the cave (Pugsley 1984).

There has been considerable controversy over the classification and evolutionary development of this fascinating organism. Goldschmidt (1948) used it as an example of saltation (sudden major evolutionary change), pointing out that its classification in the family Mycetophilidae would require that carnivory, fishing threads, and luminescence all evolve at the same time. Soon after, Goldschmidt (1951) modified his previous concept by giving numerous examples of intermediate stages of some of the creatures. The organism has since been placed in the family Keroplatidae (Matile 1981), which has closer affinities to the specialized features. Mayr (1960) and Gould (1986) have criticized Goldschmidt's 1948 saltation example. Both appear to be fighting a "straw man", since they ignore his 1951 revision.

Creationists also have some questions to consider. Is this ingenious, carnivorous, and even cannibalistic system the result of intelligent design? Does it represent modification since creation? Or is it the result of degeneration of a more innocuous system? Was predation of insects part of the original plan of creation? Were such animals as the anteater part of God's original design, or do they represent anatomical and/or behavioral modifications since creation?

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ROTORUA REGION

There is much of geologic interest in the vicinity of Rotorua. The Geological Society of New Zealand has published an excellent little guide which will be used for this part of the conference. The reference is:

Houghton, B. F. 1982. Geyserland: A guide to the volcanoes and geothermal areas of Rotorua. Geological Society of New Zealand Guidebook No. 4.

VOLCANOES SOUTH OF ROTORUA

Location

The Taupo volcanic region centers around Lake Taupo. The best views of the volcanoes in Tangariro National Park are from the W side along Highways 47, 4, and 49 in that order if you are traveling S.

Stratigraphic Position

Probably all Quaternary.

I. Taupo Eruption

The ca. 186 A.D. Taupo eruption is considered to be one of the largest volcanic eruptions in recent history. Wilson & Walker (1985) have given a comprehensive summary. It centered around the region of the Horomatangi Reef near the ESE shore of the present Lake Taupo. Study of the volcanic deposits in the vicinity reveals a complex of activity that at times involved subaqueous activity and profuse ash production that increased with time. An estimated 23 km^3 of airfall deposits from one episode extended to the E, well into the Pacific Ocean 300 km away. The climax was the production of the Taupo Ignimbrite (ash flow deposits) which has a volume of around 30 km^3. It "erupted as a single vent-generated flow unit over a time period of ca. 400 S and was emplaced very rapidly" (Wilson 1985). Local velocity of spread is estimated at more than 250-300 m/sec. The flow spread in all directions from the source for a distance of about 80 km. Reduced activity followed. A total volume of 105 km^3 of ejecta is postulated. The Taupo volcano has been called an inverse volcano, because its topography appears reversed. In contrast to normal volcanoes, it is lowest around the vent (Lake Taupo), which is lower than any point up to 40 km away. This peculiarity is attributed to tremendous explosions that extruded volcanic materials so powerfully that they did not accumulate close enough to the vent to compensate for the loss of material extruded from below. Earlier periods of activity before this major eruption have been described (Healy 1964, Vucetich & Pullar 1973). At present (1985-1990) seismicity is concentrated around the central and S part of Lake Taupo (Sherburn 1992). The region N of the lake is extending about 18 mm/yr in an E-W direction (Darby & Williams 1991).

II. Tongariro National Park Volcanoes

A good general description is given in "The Restless Land: The Story of Tongariro National Park" (1981). Tongariro National Park has 3 main volcanic peaks. From N-S they are Tongariro (1968 m), Ngauruhoe (2201 m), and Ruapehu (2797 m). Below the volcanoes are significant marine sedimentary deposits. The volcanoes themselves are a recent addition.

Mt Tongariro (1968 m) is a complex of many volcanic vents assumed to have formed over the past 2 Ma, based on K-Ar dating. The mountain is thought to have once been cone-shaped like Ngauruhoe, but after a violent explosion it collapsed, and 9 new craters were formed. Other vents formed later. These interpretations have been the subject of some controversy (Gregg 1960). On the flat top of Tongariro is a small circular crater towards the NW. To the SE of the volcano is Blue Lake, and on the N slope is Ketetahi Hot Springs and associated thermal activity.

Mt Ngauruhoe (2201 m), just to the S, is sometimes considered part of Tongariro. Its almost-perfect cone reflects slow continuous development in contrast to destructive explosive behavior. At its top is a crater about 0.5 km in diameter which frequently changes configuration. It is the most "continuously" active of the volcanoes of New Zealand. Activity began about 2500 yr ago, with most of the 900-m high cone being developed early in its history. Maoris witnessed the activity of the mountain prior to colonization by the Europeans. Gregg (1960, pp. 60-61) records over 50 eruptions between 1839 and 1959. During the 1954 eruption, boulders 15 m in diameter were ejected, and lava was ejected more than 300 m into the air. Gregg (1960, p. 66) quotes from Bidwell, who climbed to the crater in 1839:

> *The crater was the most terrific abyss I ever looked into or imagined. The rocks overhung it on all sides and it was not possible to see above 10 yards into it from the quantity of steam which it was continually discharging. From the distance I measured along its edge, I imagine it is at least a quarter of a mile in diameter, and is very deep. The stones I threw in, which I could hear strike the bottom, did not do so in less than seven to eight seconds; but the greater part of them I could not hear. It was impossible to get on the inside of the crater, as all sides I saw were, if not quite precipitous, actually overhanging so as to make it very disagreeable to look over them.*

To the S of Ngauruhoe is Ruapehu, the highest point (2797 m) on the North Island. It is considered much older than Ngauruhoe but younger than Tongariro (Suggate 1978, p. 661). Its complex history has resulted in many collapsed craters along the length of the mountain. Now in its most southerly position, the main crater is usually filled by hot Crater Lake. Gregg (1960, p. 26) reports 6 small glaciers radiating from the summit of Ruapehu. When an eruption takes place or when there is gravitational collapse, sediments accumulate along the slopes. Sometimes, water mixed with the volcanic materials can flow down the side of the mountain as a mudflow (lahar) which can form a hummocky topography near the base of the mountain, such as can be seen at the junction of State Highways 47 and 48. This locality has recently been interpreted as a combination of debris avalanche and overlying lahar (Palmer & Neall 1989, Palmer 1991).

On 24 December 1953 the release of water from Crater Lake, probably due to its high level and the collapse of ice, resulted in a lahar which undermined the railway bridge over the Whangaehu River W of Tangiwai.

Unfortunately, at the same time the Wellington-Auckland Express arrived, and 151 people perished in New Zealand's worst railway disaster. In 1975 (Nairn, Wood & Hewson 1979) another eruption occurred in Ruapehu Crater Lake. Crater dilation had been observed 2 weeks earlier. The lake level was lowered by 8 m. It is estimated that at least 1.6 million m^3 of ejecta were spread to the environment, some causing major river flooding, damaging ski and hydroelectric power constructions and bridges.

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CASTLEPOINT

Location

The geologic features of special interest are located just S of the settlement of Castlepoint on the E coast of the North Island. Castlepoint lies about 40 km E of Masterton.

Stratigraphic Position

The Castlepoint Headland and Reef are composed of the Pleistocene Castlepoint Formation. To their W is the Miocene Whakataki Formation which contains excellent examples of turbidites.

Description

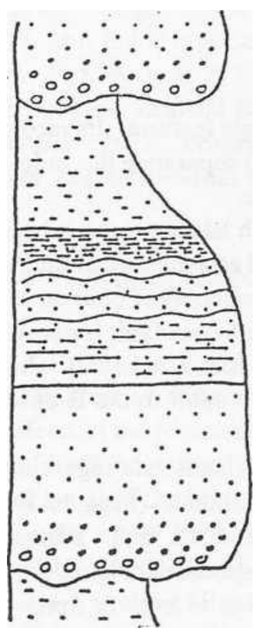
The general geology of the area has been described by Johnston (1973). The prominent headland at the S end of the bay was named the Castle by Captain James Cook. It is 162-m high and is composed almost entirely of the highly fossiliferous Pleistocene Castlepoint Formation. The reef, which separates the N part of the bay (under the lighthouse and S-ward) from the open ocean, is composed of the same formation. To the E of the bay and N and S from here are turbidites of the Miocene Whakataki Formation. The coast to the W and S displays several terraces covered with Late Quaternary marine deposits on their surfaces (Johnston 1973, Ongley 1935).

Several near-vertical faults have been described in the point and reef region. The 2 main ones run N-S and are located on the E and W sides of the point and reef. Both are downthrusted to the E and may have controlled the erosion around these features.

Fossils — especially molluscan shells — are abundant throughout the Castlepoint Formation. Powell (1937), who places the shells in the Pliocene, identified 35 species. One of the rich fossil localities is found on the W side of the middle of the reef portion. Moa remains have been found in the Holocene sands forming the hillsides N of the bay.

While the prominent ridge forming the E margin of the bay has been called a reef — an ill-defined term —, it does not give evidence of being a true wave-resistant ecological or biological reef that would have taken a long time to develop. The deposit appears transported. It is formed of well-bedded units including sandstones and much coarser horizontal deposits. Also, there do not appear to be the organic frame builders necessary to produce the wave-resistant structure of a true reef.

On the E-facing coastal cliff a couple of km S of Castlerock at intertidal level and for many meters above is a very good series of turbidites located in the Miocene Whakataki Formation. A complete Bouma turbidite sequence can be found in many of these. Usually turbidites do not show a complete sequence. The Bouma sequence consists of the following 5 units:



a	massive graded
e	interturbidite
d	upper parallel laminae
c	convoluted laminae
b	plain parallel laminae
a	massive graded
e	interturbidite

Turbidites with fewer Bouma units can be found in the roadcuts along the highway going N from Castlepoint before the junction with the road to Whakataki.

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ALPINE FAULT

Location

In its broadest interpretation, the Alpine Fault runs the length of New Zealand, but the best localities for viewing it are on the South Island. One spectacular view is at Lake Rotoiti, 40 km E of Murchison. From the settlement of St Arnaud on the lake, the fault runs to the SW (and NE) through Mt Robert. When facing SW, the fault lies on the shoulder on the NW side of Mt Robert. Another good view is obtained looking NE from the region 20 km E of Kumara along Arthur's Pass Highway 73. There the fault is the cause of the long valley to the NE. The most dramatic expression is found on the W face of the Southern Alps, which are the result of the uplift on the E side of the fault. The town of Franz Josef near the W coast of the South Island lies on the Alpine Fault.

Stratigraphic Position

Varies according to location of fault.

Description

The Alpine Fault is one of New Zealand's most famous geologic features. Its incorporation into the plate-tectonics model as a transcurrent fault (large-scale, strike-slip fault) separating the Indo-Australian Plate on the NW from the Pacific Plate on the SE has increased its importance.

The Alpine Fault is well defined on the main part of the South Island, where it branches into a number of other faults toward the N. On the North Island it may be expressed as a number of faults in a NE-SW direction, or may lie E of the North Island. There is an unfortunate lack of unanimity of opinion as to when and what may have happened along the Alpine Fault. It is agreed that it is a right lateral fault (opposite side to the right) and that its main expression, at least in the N and S part of the South Island, is lateral, while in the central region it represents compressional movements (Suggate 1978, p. 698), with uplift to the E of the fault resulting in the Southern Alps.

Wellman & Cooper (1971) have summarized some of the pertinent data regarding the amount of lateral motion along the fault. Figures as high as 480 km are based on "tenuous" (Suggate 1978, p. 320) evidence of matching formations between Nelson and Otago on opposite sides of the fault. Belts of mylonite (pulverized rock) on opposite sides suggest at least 230 km, while lamprophyre (special dark igneous rocks) dike belts suggest 120 km. Estimates of present rates vary from about 300 cm/1000 yr to over 10 times that rapidly (Coates & Chinn 1991).

Estimates of total uplift and rates of uplift also vary. Suggate (1978, pp. 678, 696) and Bull & Cooper (1986) report estimates of around 10-20 km of total uplift and current rates of uplift from 121-1064 cm/1000 yr. Wellman (1979) reports rates up to 1700 cm/1000 yr.

It is generally agreed that movement along the Alpine Fault has been episodic. There is some agreement that major lateral motion occurred during the Cretaceous Rangitata Orogeny, while uplift has dominated the more recent Miocene to Quaternary Kaikoura Orogeny. Dating of the movement by the K-Ar method has been complicated by the traumatic effects of movement along the fault, causing escape of argon gas. Sheppard, Adams & Bird (1975) found low dates along the fault compared to the surrounding rock. For one sample, Wellman & Cooper (1971) reported a whole rock date of 136 Ma, 90 Ma for hornblende mineral samples (assumed due to loss of Ar) and 1343 Ma for plagioclase mineral samples (assumed due to absorption of Ar by the mineral).

The rapid rates of uplift noted for the Southern Alps at present cannot be extended very far back into time. Adams (1980) takes some exception to this. Why is the region so active now? In addition, this phenomenon of rapid orogeny is not restricted to the Southern Alps, neither is current rapid geologic action restricted to the question of orogeny. Several lines of evidence suggest that past rates of change must have been different from the present (Roth 1986). Could our current flurry of activity represent the lingering effects of the more chaotic worldwide flood described in Genesis?

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MURCHISON AND INANGAHUA EARTHQUAKES

Locations

The effects of these 2 major earthquakes can be seen at 3 stops along Highway 6, SW of the town of Murchison. 1) Some effects of the Murchison earthquake are clearly displayed at a road sign at the White Creek fault on the S side just W of the narrow bridge over White Creek, which is about 4 km W of the junction of highways 6 and 65, or 2 km E of the bridge over Newton River. 2) Between 11.5 and 12 km further SW along highway 6, a look down the upper Buller Gorge Canyon shows a number of dead trees near the level of the river. These were killed by inundation when a slide of the Inangahua earthquake dammed the Buller River. 3) Three km further to the SW along Highway 6 is a turnout SE of the road. From here a large slip dominates the hillside across the Buller River, while a river-level view shows an old earthen dam (slip) which has been eroded by the river. This dam killed the trees seen at the previous stop. Both the dam and the slip were the result of the Inangahua earthquake.

Stratigraphic Position

The White Creek Fault locality is in Holocene river deposits and Oligocene sediments in the terraces further to the S. The slips visible further to the W are in the Precambrian(?) to Permian(?) Tuha Group, which is a composite of granite and granitic-like metamorphic rocks (Bowen 1964).

Description

The display sign at White Creek Fault explaining the Murchison earthquake is located approximately on the White Creek Fault which runs N-S (perpendicular to the road). Immediately after the earthquake (magnitude 7.75), which occurred on 17 June 1929, there was a 4.5-m vertical offset of the road. The older terraces of the Buller River, seen to the S across the river, still show the offset caused by the fault, with the right (W) half of the terraces lower than the left (E). The reverse fault slippage, as measured at the lower terrace, showed a vertical offset of 3.1 m and a sinistral (left lateral) offset of 2.1 m. The terraces were not faulted prior to 1929. The vertical displacement decreases regularly N and S from the road. Maximum displacement did not take place at the fault scarp itself, but about 1.2 km to the E where it was 4.9 m (Berryman 1980). The epicenter of this earthquake was about 4 km S of the terraces. An intensity of MM 11 is also reported with numerous aftershocks, with at least 6 being MM 7 or greater (Eiby 1968). Berryman (1980) reports that red beech growing on the hill across the river S of the upper terrace have distinct bends in their trunks. The bend is assumed to have been caused by tilting of young trees during the 1929 earthquake. The tilted trees have grown wider rings on the underside of the trunk, and asymmetric growth of the rings started 46 rings (years) before they were studied in 1975, which brings them back to 1929, the date of the earthquake. The Murchison (Buller) earthquake caused severe damage in the town of Murchison with the loss of 17 lives.

The 23 May 1968 Inangahua earthquake had a magnitude of 7.0. Its epicenter was about 25 km W of the Murchison earthquake and 15 km N of the town of Inangahua. Focal depth was about 12 km. Three deaths and 14 injuries resulted. Railway lines at Inangahua were disturbed, and some houses were destroyed. Intensity is estimated at MM X. In the Buller River Gorge there were major slips, including damming which caused temporary high water along the river, killing the trees near the bottom. Damage extended to the towns of Reefton, Greymouth, and Westport, where unconsolidated ground reached MM X (Adams, Suggate & Skinner 1968). Hunt (1970) reports that a regional uplift of 2.7 m was noted near Inangahua after the earthquake. The apparent increase in mass is attributed to thrust faulting.

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DENNISTON REGION

Location

From the town of Westport, proceed N along the coast highway to Waimangaroa. Take the road to the SE up the monocline of the W side of the Paparora Range to the coal-mining town of Denniston. About ¼ of the way up, you will pass debris flows in the roadcuts. The later part of the road exposes coal seams.

Stratigraphic Position

The coal seams and associated sediments around Denniston form part of the Upper Eocene Brunner Coal Measures (Laird & Hope 1968). Stratigraphically above, but due to seep folding actually found along the road below, is the overlying Upper Eocene Kaiata Formation, which typically consists of dark-colored micaceous marine siltstone and sandstone (Laird 1968) and contains a number of debris flows.

Description

The 600-m hill between Westport and Denniston is a part of a large steep monocline which incorporates the Paparoa Tectonic Zone (Laird 1968). This zone extends N into the Karamea Bight and S to the town of Hokidka. The comparable sedimentary units on top of the monocline at Denniston are at least 4 times as thick as those further down at Cape Foulwind W of Westport and are interpreted as representing thick sedimentary deposits of the narrow N-S tending Paparoa Trough. The Paparoa Tectonic Zone has apparently been active since the Cretaceous (Lewis and Laird 1986).

On the way up the hill the Eocene Kaiata Formation is exposed in several roadcuts. Sometimes the layers are almost vertical from the postdepositional monoclinal uplift to the E. Numerous debris flows have been identified. Clasts include rafts of mudstone, etc., and other rock fragments up to many meters in maximum dimension (Lewis & Laird 1986), suggesting catastrophic levels of activity.

Several coal seams are exposed along the roadcuts near Denniston. Some reveal parallel coal layers and clastic partings, which would suggest allochthonous (transported as expected during a flood) deposition for the Eocene Brunner coals.

Denniston is a dwindling coal mining town. Most of the miners now live in Westport where the climate is more salubrious. The town rests on striped Eocene Brunner Coal Measures which contain both low and high sulfur coal. Both open-pit and underground mining are used to extract the coal. Now transported by truck, the coal was formerly loaded on an endless bucket system and then transported down the famous Denniston incline in rail cars controlled by cables. The remains of this system are well-displayed at the W edge of town.

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CONSTANT GNEISS

Location

One of the best localities to view the Constant Gneiss is at picturesque Constant Bay, located just W of the little settlement of Charleston, which is about 26 km S of Westport on W coast Highway 6.

Stratigraphic Position

The Constant Gneiss is considered to be Precambrian.

Description

During its prime, Charleston, a former gold-mining town, is said to have had 12,000 inhabitants who lived mostly in tents. The boom started in 1866 and began declining 2 years later. Gold came from the sands and terraces of the region. A New Zealand commercial gold mine is N of Charleston. Multi-masted schooners carrying the ore would try to maneuver in and out through the narrow inlet to Constant Bay. Not all succeeded.

The Constant Gneiss is exposed in several regions within 50 km N and S of Westport, as well as in isolated larger exposures, several hundred km^2, which are found further inland from the coast. It is usually considered to be stratigraphically below the Greenland Group (see the Greenland Group Turbidite locality description). Its composition is a complex of igneous and sedimentary rocks, forming a mixture of granite, gneisses, schists, etc. These rocks enclose Constant Bay.

The assumed age of the Constant Gneiss is debatable. Bowen (1964) and earlier workers (reported in Aronson 1968) offered a Precambrian age. Laird (1967) proposed that the Constant Gneiss represented metamorphosed Greenland Group, while Aronson (1968) and Shelley (1970) suggested it was probably Middle Paleozoic. More recently Adams (1975a), using samples from the Charleston region which he considered to be primary, obtained an isochron line of 680±21 Ma with the Rb-Sr method. This classified the original rocks as Precambrian. It is generally agreed that some of the rocks and/or minerals have been subject to several episodes of metamorphism, which would vary the apparent ages by partial or complete resetting of the radiometric clocks. Zircon crystals date from 316-398 Ma using U-Pb methods (Aronson 1968), micas date from 104-212 Ma by the Rb-Sr method (Aronson 1968) and 8588 Ma with the K-Ar method (Adams 1975b). These relatively younger mica dates are attributed to alteration resulting from the Mesozoic Rangitata orogeny.

The same kind of phenomenon has been noted in the surrounding region with younger K-Ar dates occurring closer to the Alpine fault. The younger dates are attributed to loss of radiogenic Ar (Wellman 1990). Fission-track dating reflects a little of the same, with zircon-crystal dates about 3 times as old as apatite dates. The older zircon dates are explained as coming from more resistant minerals showing less annealing of the tracks by pressure or temperature (Seward & Nathan 1990, Seward & Tulloch 1991). This illustrates the anomalies and interpretations that are common in dealing with radiometric dates.

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PUNAKAIKI PANCAKE ROCKS

Location

The rocks can be seen at the well-appointed reserve just W of W coast Highway 6, S of the settlement of Punakaiki which is about halfway between Greymouth and Westport.

Stratigraphic Position

Pancake Rocks are Oligocene Potikohua Limestone.

Description

Pancake Rocks at Dolomite Point (no dolomite) form a most striking set of limestone layers, due to the differential erosion which appears greatest near the top of each layer. The area is best known for its erosional configuration at sea level which, during certain tide and wave conditions, generates a respectable jet of water through its blowhole.

The usually regular bedding of the limestone that forms the Pancake Rocks is of interest. Some attribute it to depositional patterns with more easily eroded mudstone at the top of the layers; others to post-depositional factors. Unusual conditions would be involved in such a regular depositional pattern. It could reflect storm or tidal activity associated with a proper source for limestone or other factors. In terms of the Genesis flood, this Oligocene deposit might be caused by the "going and returning" (Genesis 8:3, KJV margin) of the receding waters of the flood, with marine lime sediments as a *source* for the deposits.

At the base of the layers of "pancakes", where the rock is more massive, is the Marshall Paraconformity (Carter & Landis 1972). A paraconformity (disconformity) is a widespread parallel contact between rock layers, here a significant amount of time is assumed to have elapsed between the layers. The time gap in the Marshall Paraconformity is assumed to be about 3 Ma (or as much as 4-15 Ma) (Carter 1985). Most paraconformities show a striking lack of the passage of the assumed time, such as erosion channels and deposits, and weathering (Newell 1984). They are identified mainly on the basis of standard dating procedures, fossils, and correlation with other layers.

The general lack of physical features representing the passage of time at paraconformities is a problem for the standard geologic time scale (See the section on "Disconformity at Clifton" in NSW for further discussion).

At Punakaiki the contact seems flat; however, some irregularities have been reported (Carter, Lundqvist & Norris 1982). The Marshall Paraconformity contains a concentration of phosphate minerals (Carter, Lundqvist & Norris 1982) which are interpreted as requiring some time for formation. Carter (1985) points out the incongruity and problems of these paraconformities. Referring to the Marshall Paraconformity, he states that "up to 15 my of evidence may be concentrated along a single bedding plane." Interestingly he also comments that "no instances of sediments or features characteristic of subaerial exposure have yet been described from on or just above the Marshall Paraconformity." However, Loutit & Kennett (1981) propose a drop in sea level at the time of the formation of the Marshall Paraconformity, which might be expected to give evidence of subaerial exposure. The Marshall Paraconformity is assumed to be widespread, including New Zealand, South Australia, and even more distant areas such as Papua, the New Caledonia Basin and Lord Howe Rise (Carter & Landis 1972). Some authors believe that it needs better definition (Findlay 1980, Lewis & Belliss 1984).

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GREENLAND GROUP TURBIDITES

Location

Good exposures of the Greenland Group can be found along W coast Highway 6, N of Greymouth between Fourteen Mile Bluff and Seventeen Mile Bluff. A good area to see turbidites is at Fourteen Mile Bluff (low tide area), which is about 2 km N of the settlement of Greigs. At low tide the vertically oriented sedimentary layers to the W of the road show fairly complete turbidite sequences.

Stratigraphic Position

The Greenland Group is now considered to be Ordovician. Earlier views suggested it was Precambrian.

Description

The Greenland Group in this area is mapped for several hundred km^2. Larger areas are described along the coast several hundred km to the S. Closer to the E in the Reefton area, it is represented as the related Waiuta Sequences which are sometimes considered identical (Laird 1972).

The stratigraphic age of the Greenland Group has been difficult to establish. The almost-complete absence of fossils precludes good correlation with related deposits. Cooper (1974) described a graptolite that is considered Lower Ordovician. Graptolites are a colonial type of organism that looks like a small branched seaweed.

Now considered to be animals, their classification remains problematic. Radiometric methods give dates from 298 to 494 Ma (Adams 1975a,b; Adams, Harper & Laird 1975). Detrital (from another source) zircons give discordant dates of 1170-1480 Ma and are interpreted as minimal (Aronson 1968). A sample from the Fourteen Mile Bluff locality gives a K-Ar age of 300 Ma (Adams 1975a). The variety of dates are interpreted in part as representing various metamorphic events (Adams, Harper & Laird 1975) which reset the clocks.

The Greenland Group (Laird 1972) consists of sandstone and mudstone sequences interpreted as a turbidite succession. Fairly complete Bouma sequences witness to the rapidity with which the layers have been laid down. Other evidence of rapid deposition include directional sole marks (gouges), load casts (foundering), and flame structures (injection of one unconsolidated layer into another). The quartz-rich sediments were derived from the E or SE, possibly from a granitic source, and deposited in a submarine fan complex. Laird & Shelley (1974; zee also Shelley 1975) described in some localities a secondary lithological layering parallel to the slaty cleavage, but not parallel to the original bedding. They interpreted this "as the result of grain movement in wet, unconsolidated sediments undergoing compression." They originally saw a time conflict between the time of deposition of the Greenland Group (Ordovician) and the later disturbance that would have produced the secondary layering. They state, "'How long could the Greenland Group sediments have remained wet and unconsolidated before the probable time of granite intrusion in the Devonian and Carboniferous (see Aronson 1968)?'" The dating conflict was resolved by proposing (Adams, Harper & Laird 1975) that the metamorphism producing the slaty cleavage occurred earlier during the uppermost Ordovician, instead of its being the result of the major Carboniferous Tuhuan Orogeny proposed earlier.

The development of slaty cleavage while sediments are being dewatered was proposed by Maxwell (1962) and subsequently endorsed by a number of authors. As with most interpretations of the past, the concept has not gone unchallenged (e.g., Beulner 1980).

It is of interest to a model of the Genesis flood that both the turbidites and the development of secondary layering in soft sediments can suggest rapid action.

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FOX AND FRANZ JOSEF GLACIERS

Location

The access roads to the Fox and Franz Josef Glaciers are signposted from the towns by the same name. The best views of the foot of the glaciers are reached by taking the road to the S of the Waiho River for the Franz Josef Glacier and the one to the N of the Fox River for the Fox Glacier.

Stratigraphic Position

Both glaciers cut their valleys through the metamorphosed Haast Schist Group, which is Triassic to Upper Paleozoic (Gair 1967, Warren 1967). The E part of the glacial source area snowfield lies over Jurassic Torlesse Supergroup. At the W end of the glacial valleys lies the NE-SW tending Alpine Fault. The towns of Fox and Franz Josef are located just W and on the Alpine Fault respectively. To the W of the Alpine Fault lies Pleistocene and Holocene river and glacial deposits.

At the foot of both glaciers, typical examples of metamorphic rocks such as grey schists, chlorite schists (green), and gneiss can be found.

Description

Both glaciers come from an icefield (neve) located N of Mt Cook (3813 m). In general the glaciers have been retreating. This means that while they continue to flow as they are fed from their ice-field source, they are melting faster than they are replenished. Occasionally they advance, pushing masses of rock ahead of the foot of the glaciers. When they resume their retreating, they leave masses of unsorted rubble as ridges of rocks called terminal moraines. Many of these can be seen at the foot of both glaciers and are sometimes identified with a date to give an idea of the rate of retreat. Glaciers also deposit transported rocks along their sides. These are called lateral moraines. As glaciers travel and melt, encased rocks tend towards the surface, as is evident in both glaciers.

When viewing the glaciers, look for small "kettle lakes" left by the glacier in the floor of the valley. These lakes are caused by melting blocks of ice. Also look for older tree lines along the walls of the valleys. Glacial striations left by rocks pushed by the glacier are common on hard rock surfaces. Near the foot of Franz Josef Glacier, several lateral faults can be seen in the valley walls. Paradoxically, these appear to be left-lateral faults (opposite side to left), while the Alpine Fault, just to the W, is a right-lateral fault. Recent studies propose that these faults near the foot of the glacier are actually right-lateral faults because the fault surfaces appear to be right-lateral. The opposite offset in the walls of the valley is attributed to secondary factors (Hanson, Norris & Cooper 1990).

A. Fox Glacier

As you drive to the carpark near the foot of Fox Glacier, note the dates of the various terminal moraines. The glacier has been stable during the past few years. The glacier starts at an altitude of about 1.5 km and descends to 300 m. Some of the ice from the snowfield travels as far as 13 km to the foot of the glacier. The glacier is about 60-m thick at the top and twice that thick at its foot. Rate of flow in the past has averaged between 7 and 54 cm/day (Suggate 1950).

In the lateral and terminal moraines are blocks of ice. Several kettle lakes may be visible on both sides of the valley. Across from the carpark to the S, note the faint 1750 trimline and lower 1820 trimline (large trees above) and horizontal glacial striations left by the scraping of rocks carried by the glacier. Cone Rock and associated features on the S side of the valley are of more resistant, vertically oriented schists which have withstood glacial erosion.

B. Franz Josef

Note some of the same features described above. The glacier flows faster than Fox Glacier, in part because it has a smoother bed as well as a straighter course of flow. Its rate of flow has been recorded between 12 and 515 cm/day (Suggate 1950). While it is generally retreating, Suggate (1978, p. 622) reports some periods of advance between 1915 and 1930, 1943 and 1950, and 1965 and 1970. Some advance has also been noted between 1980 and 1990.

The Waiho River, which comes from the glacier, is famous for its capriciousness. Two quotations describe an incident in 1965:

> *Following heavy rain at Franz Josef on 16 and 17 December 1965 when 11 in. were recorded at the township, a large washout of ice and scree material on the western side of the valley occurred in the early hours of Sunday, 19 December. A section of the terminal face, 30 m (100 ft) wide and extending up the western side of the glacier for 300 m (1,000 ft) . . . was completely washed out. With the advance of the glacier the ice became heavily crevassed. . . and it is generally thought that much of the water. . . became trapped in the crevasses until sufficient pressure was built up for it to burst out. At least 800,000 cu.m (1,000,000 cu. yd) of ice and probably as much scree material were estimated to have been carried down the valley. Ice was scattered over parts of the access road and down the Waiho River to the sea coast. The scree material was carried down stream from the mouth of the gorge for a considerable distance. At the mouth of the gorge . .. the level of the river bed was raised at least 15 m (50 ft) above its original level* (Sara 1968).

> *A different kind of contrast in age and tempo is illustrated by cyclic stream terraces. Vertically spaced by tens of feet and underlain by tens of feet of gravel, such terraces in many parts of the world have been attributed to glaciation-deglaciation cycles spanning thousands of years; yet similar features of the same magnitude are known to form, basically by the same processes, within a minute fraction of the time. A striking example was provided by the Waiho River, which drains the Franz Josef Glacier in New Zealand. During a single high-intensity rainstorm in December 1965, the riverbed was aggraded from 10 feet to about 80 feet over several miles, and in the succeeding few weeks rapid downcutting and channel shifting produced a flight of 10-foot terraces. Elsewhere in the same region, terrace flights of similar size were developed and eliminated more than once in the past 30 years by aggradation-degradation cycles presumably related to weather patterns on the 10-year order. The vagaries of erosion are such that vestiges of these terraces may survive. Colonized rapidly by plants in this moist temperate region, they soon acquire a false aspect of antiquity and in another environment might be mistaken for late Pleistocene degradational terraces* (Gage 1970).

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MOTUNAU AREA

Location

From Motunau junction (Highway 1, N of Christchurch), go E towards Motunau Beach. Just before reaching the beach, go 0.7 km N on Hurunui Road and turn E for 0.4 km on the dirt road. Proceed on foot N of river to coast and N along beach.

Stratigraphic Position

The main sedimentary deposits along the beach are the fine-laminated drab Upper Pliocene to Lower Pleistocene Greta Formation. Within these are the fine-to-coarse channel fills also considered Lower Pleistocene.

Description

The Pliocene Greta Formation, which forms the main cliff of this region, is a softer laminated siltstone and mudstone. It is well bedded. At this locality ancient shallow channels filled in with coarse-to-fine sediments form a resistant unit responsible for the presence of the peninsula and Motunau Island (Lewis & Laird 1986). These channel deposits are case hardened with carbonate cement. The deposits vary from fine to coarse, as can be seen at the beach area just N of the river, and have been classified into 4 different groups (Lewis 1976), mainly according to their coarseness. It is inferred that the coarsest deposit represents the front (head) of debris flows. Lewis (1976) also states that "there is ample evidence that Greta mudstones were not consolidated" when they were probably eroded by the debris flows. Evidence includes some large flames (upward injections) of Greta into the overlying channel debris flows and the folding of the mudstone. This would suggest little time between the two deposits. Slumping is assumed to have initiated channel formation followed by channel filling. This activity took place underwater in an environment comparable to the outer portion of the continental shelf. In 1979 Herzer & Lewis described a buried submarine canyon offshore as had been predicted earlier (Lewis 1976) by this model.

A number of cetacean bones have been described in the channels. Along the rocky beach to the N are the skeleton of a dolphin, the jawbone of a sperm whale, and whale vertebra. These also reflect a degree of rapid burial, as contrasted to the present rate of change along the coast.

A little further offshore, Carter & Carter (1982) have described the Montunau Fault, one of several faults in this region (mainly NW) possibly associated with the Alpine Fault movement.

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CANTERBURY PLAINS

Location

The Canterbury Plains form a very flat area, 150 by 400 km, on the E coast of the central part of the South Island. Christchurch is located towards the N of this extensive plain.

Stratigraphic Position

Quaternary deposits dominate most of the plains.

Description

The Canterbury Plains provide a sharp contrast to the Southern Alps which lie just to the W. The broad extent and flatness of the Plains are striking as they extend from the E coast of New Zealand to the foothills of the Southern Alps to the W.

The Plains are a depositional sedimentary environment which receive sediments from the Southern Alps by way of several major rivers flowing to the E. Total thickness reaches 600 m (Lewis & Laird 1986). The course of the rivers occasionally migrates laterally, providing new channels for the accumulation of sediment. The rivers originate from areas that have been glaciated and, as they enter the Canterbury Plains, have produced huge coalescing fans of glacial outwash which form the Plains. These fans are sometimes many hundreds of meters thick (Suggate 1978, p. 688; Gregg 1964).

The Plains do not represent an erosional surface, since they are a depositional environment. Evidence supporting this includes ^{14}C-dating which give dates of deposition as low as 2420 or even 940 yr in the Christchurch area (Suggate 1958). The region is described as an aggradation (depositional) area (Suggate 1978, p. 606). Gage (1958) described 5 distinct periods of glacial advance in the upper Waimakariri Gorge which would provide sediment for the Canterbury Plains. Many of the deposits of the Plains are now below sea level (Suggate 1958), which could represent a rise in sea level. Wellman (1979), however, gives evidence that the region around Christchurch is sinking at the rate of 0.3 mm/yr.

It has been estimated that 26% of the land surface of Canterbury is covered by loess which is defined in New Zealand as "any fine textured deposit of aeolian [wind transported] origin other than dunes" (Ives 1973).
It is not unusual for these loess deposits to be over 10-m deep. The old surfaces of these deposits sometimes have soils which have been estimated to be older than 10,000 yr by the ^{14}C-dating method. However, some caution seems warranted before accepting such dates. Runge, Goh & Rafter (1973) dated a loess sequence from Timaru Downs. The sequence of "whole sample" ^{14}C-dates descending through the layers gave 9,900, 12,000, 27,200, 17,300, and 15,650 radiocarbon years before present. The anomalous "perplexing" younger dates (17,300

and 15,650) found below older dates were explained as contamination. Various organic fractions extracted gave dates of 6,720 to 31,000 yr. A "revised" list by Tonkin, Runge & Ives (1974) included only the 9,900, 12,000, and 27,000 yr dates. Such exclusion of anomalous data can raise the question of unwarranted conformity to an accepted paradigm. It strengthens Branscomb's (1985) concern that the scientific investigator "continues searching until he gets a result close to the accepted value. Then he stops." This mode of activity can unconsciously favor the perpetuation of error.

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