# THEME 1: SITE AND LAND FORMS

## 1.1 EXTENT OF CURRENT CITY BOUNDARY

Dunedin's boundary, as drawn in 1989, encloses 3314.8 km$^2$, making it the largest city by land area in New Zealand. The city extends west to Middlemarch and north to Waikouaiti while the Pacific Ocean defines the east and south-east extent and the Waipori/Taieri River the south-west. For the purposes of this report 'Dunedin' refers to the urban centre and its suburban belt, 'Dunedin inner city' to the commercial and residential centre and 'Dunedin City' to the greatly expanded 1989 boundary.

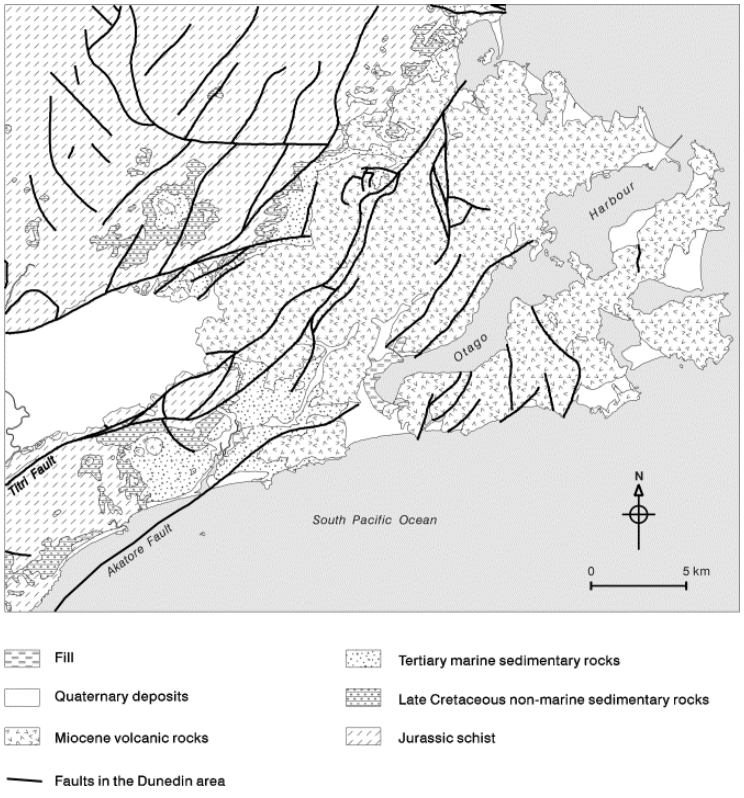


**Figure 1: Diagram showing the major fault systems in the Dunedin City area** [after McDougall & Coombs 1972]

## 1.2 GEOLOGICAL HISTORY

The natural processes (Fig. 1) that have formed the Dunedin landscape are outside the scope of archaeology (geology, geomorphology and other natural sciences address these issues), but the natural attributes of the location have provided an attraction for human habitation for both

prehistoric Maori and historic-period Europeans (and later many other races and nationalities). Despite the many modifications to the landscape wrought by human occupation, the natural landforms, underlying materials and climate all continue to dictate many aspects of our occupation of the site. Many economic activities, such as quarrying, coal and gold mining and brick making have depended on access to natural raw materials, and archaeological evidence of these activities can be found throughout the area. Thus, while the natural and geological history of Dunedin is not the subject matter of archaeology, many archaeological sites are the result of human responses to natural features and processes. This theme is explored more thoroughly in **Theme 7: Utilising The Environment**, page 130.

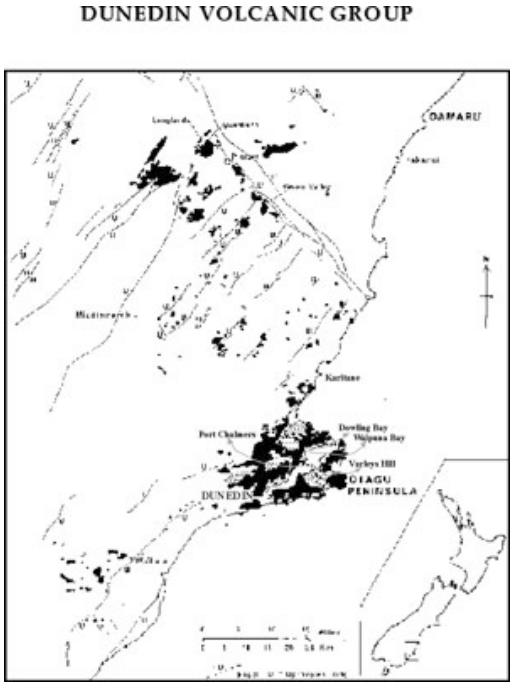


**Figure 2. Outcrops of volcanic rocks belonging to the Dunedin Volcanic Group. Mafic** rocks are black, **phonolites** and **trachytes** are stippled.
Faults active during the Kaikoura Orogeny are also indicated
[after McDougall & Coombs 1972]

**Dunedin Volcano:** The main urban area of Dunedin is sited on and around the eroded cone of the Dunedin Volcano (Fig. 2), a major shield type volcano centred on Port Chalmers and Portobello. Its highest point is Mt Cargill at 680 metres and the diameter of the cone approximately 25 kilometres, extending offshore from the Otago Peninsula. It was

active during the middle to late Miocene period between 16 and 10.1 million years ago and is long extinct. The wider system embraces the Waipiata Volcanics to the north and south. This is represented by conical eroded remnants, lava flows and dikes throughout the city area and also, more conspicuously, to the west of Palmerston. This system extends from 150 kilometres from Kaitangata north to Ngapara and includes remnants of 150 distinct episodes.

**Waipiata Volcanics:** The Waipiata Volcanics were active for a longer period than the Dunedin volcano, between 24.8 and 8.9 million years ago. These volcanoes erupted through a basement of schist covered by Cretaceous-Miocene sediments of quartz gravel, sands and clay that were initially eroded into low relief and later disrupted and folded by movement of the Pacific plate. This process became more marked around 12 million years ago (Coombs 2008).

**Dunedin topography:** The land around Dunedin today comprises clay, silt, sand and gravel with the eroded centre of the main volcano deeply filled with sediments. Large sand dunes have built up around its ocean edges. Dunedin's immediate landform is characterised by ridges and hills cut through by gullies and steep sided valleys. Its coastline varies between steep cliffs revealing considerable geological action over time and estuaries and bays that have been formed by the flooding of the cone near the urban centre, erosion and the action of rivers and streams on the surrounding plains. Less than 10% of the Dunedin inner city area is flat to gently sloping ground. While its surrounding landscape is defined by folding, volcanic eruption and faults, Dunedin is located in one of the least seismically active areas in New Zealand.

**Flooding and sedimentation:** Faulting and warping caused the harbour to be lowered in relation to the surrounding hills. The rise in sea level following the last period of glaciation flooded this valley, creating the Otago Harbour. It is divided laterally by a ridge extending from Port Chalmers across to Portobello, indicating that the harbour was once two separate river systems. Changing sea levels over time have seen the Dunedin Volcano set both deep inland and partly under the sea. The encroachment of sea across the Dunedin area resulted in the formation

of deep sedimentary deposits, including marine mudstone, siltstone, sandstone and some limestone to a thickness of 900 metres. From earliest to most recent, these are: the Abbotsford Formation formed from mudstone and fine sandstone; Green Island Sand, which is a poorly cemented fine to medium sandstone; Burnside Mudstone, a silty clay mudstone; and Caversham Sandstone, a moderately well cemented fine sandstone. Wind-transported silt and clay (loess) is widespread in the Dunedin area with the most recent phase coinciding with the last glaciation, between 14,000 and 20,000 years ago. Colluvium cover is made up of a mixture of volcanic boulders of up to one metre in diameter combined with smaller rocks, pebbles, sand, silt and clay produced by the wearing away of exposed bedrock materials.

## 1.3 ECOLOGY

**Figure 3: Sawyers Bay, Port Chalmers and Otago Harbour.**

Dunedin City contains distinct ecological districts comprising different bio-climatic zones supporting a variety of indigenous vegetation and wildlife (Fig. 3). Due to its relatively small proportion of developed to open land, Dunedin City encompasses areas of indigenous forest, coastal and high country habitats. Rare or unique habitats include the

cloud forest of the Leith Saddle, and coastal and estuarine habitats such as the Aramoana salt marsh. The Aramoana Ecological Area includes low sand flats within an estuarine environment containing wetlands, herb swamp and salt marsh, providing habitat for sea and shore birds and insects.

**Plant cover:** The plant cover of the coastal districts of Otago over time is reasonably well understood. Pollen records covering the last 12,000 years have been published showing that the area around Dunedin was grassland and shrub land with small scattered patches of forest during the late Pleistocene epoch (126,000 ± 5,000 years ago). Around 10,000 years ago tall podocarp forest dominated by Dacrycarpus, Prumnopitys and Podocarpus spread in response to a warming cycle. Later, Dacrydium cupressinum became the most abundant tall podocarp tree and Nothofagus menziesii spread in the uplands responding to cooler conditions and higher rainfall. The Dunedin area was formerly covered in native podocarp-broadleaf forest that has now largely been replaced by urban and suburban developments, grassland pasture and pinus Radiata plantations around the urban fringe.

**Otago Peninsula:** Large areas of the Otago Peninsula are maintained as a natural habitat by the Otago Peninsula Trust. The Peninsula is the habitat of a number of rare species including Yellow-eyed Penguin (Megadytes antipodes) (Hoiho), New Zealand Fur Seals (Arctocephalus forsteri) (Kekeno), Hooker's Sealion (Phocarctos hookeri) (Whakaho) and different species of shags. Significantly, it is home to the world's only mainland breeding colony of Northern Royal Albatross (Diomedea epomophora sandfordi) (Toroa-whakaingo), at Taiaroa Head on the Peninsula's north-eastern headland.

## 1.4 UNDERLYING LANDFORMS

**Volcanic stones:** The underlying landforms in the Dunedin City area comprise a diverse range of geological structures resulting in a variety of surface characteristics. The main features within the Dunedin inner city area are the eroded remnants of the Dunedin Volcano evident in

exposed rock faces throughout the area. The Dunedin Volcanic Group deposited many different types of rock in the period during which it was active. The majority are basalts and phonolites ranging from a moderately unsaturated alkali-basalt to trachyte lineage and a strongly undersaturated basanite to phonolite lineage. Additionally, a breccia found at Port Chalmers proved a useful material for construction purposes. Port Chalmers breccia is a bluish-grey colour and was used to construct the Port Chalmers Graving Dock now buried under the container wharf reclamation. Stone for kerbing used in Dunedin and Port Chalmers was extracted from the same source.

Exposed rock can also be seen in the central city at the base of Bell Hill and on Burlington Street. Active and disused quarries are located throughout the wider city environs including Andersons Bay, Sawyers Bay, North Road and Upper Junction Road. Columnar basalt formations can be seen strikingly at Blackhead. These stones were widely used in building and engineering works throughout the 19th century and can be viewed in many places in Dunedin, including the Dunedin-Port Chalmers Railway embankment which runs under and alongside State Highway 88 as well as in the basements and side walls of many 19th century buildings.

**Streams and watercourses:** Major water courses in the Dunedin City area include the Taieri, Waipori, Shag and Waikouaiti rivers. Dunedin's main water supply is drawn from Deep Stream, Deep Creek, and the Silver Stream, supplemented by bores on the Taieri Plain. The inner city is crossed by Lindsay Creek, Water of Leith and Kaikorai Stream.

Visible reminders of the geology and hydrology of Dunedin can be seen in many places in the inner city where long hidden watercourses emerge in flood conditions to surprise property owners. Old streams remain above ground in many places in the city and inner suburbs while the Toitu flows through a large culvert under Princes Street, the first of which was constructed in 1858 to hide what had become an open sewer. What appears as an illogical meandering of streets near Albany Street traces the original shoreline at the mouth of the Water of Leith. While partially quarried, the very steep sides of Leith Valley have not

been built on and Woodhaugh Gardens contains a remnant of original vegetation including kahikatea, matai, lacebark, ribbonwood and lemonwood. Old Leith valley flood channels are visible in the bush, although the bed of the stream has been lowered for flood protection.

**Land movement:** The outer northern edge of the urban centre is defined by the peaks of Flagstaff and Mt Cargill and Swampy Summit which rise to between 650-750 metres above sea level. These peaks are connected by two parallel ridges which extend northeast, joining the Leith Saddle which is traversed by State Highway 1 into Dunedin. Dunedin's underlying geology is often revealed in road construction along this route. The Kilmog area north of Dunedin city is a volcanic intrusion into a raised section of the Otago peneplain, covered by sandstone. This area is prone to slumping, leading to regular re-levelling of State Highway 1. This unstable formation extends to the coast at Seacliff and doomed R. A. Lawson's Seacliff Lunatic Asylum (1884) which was demolished in various stages, the main block falling in 1959. Some areas of Dunedin, most notably around Abbotsford and Saddle Hill, are subject to earth flow and landslides where a combination of moderate to steep slopes, weak and unstable rock types, and rainfall result in instability. This was made dramatically evident in the 1979 Abbotsford landslip which involved the destruction of 70 properties (Glassey 2002).

**Taieri Plain:** East of the urban centre of Dunedin lies the Taieri Plain, a basin bounded by extensive fault systems. The Titri Fault System is approximately 60 kilometres in length. Movement along this fault has caused the Haast Schist basement to drop unevenly to where it now lies between 50 and 300 metres under the surface. The area was filled by the sea 10,000 years ago and drilling near the Dunedin Airport shows silt, sand and gravel to a depth of 154 meters. The Taieri River now cuts through this softer material.

**Strath Taieri:** The Strath-Taieri is a high valley that lies at the northwest extent of Dunedin's current boundary. The shallow and tidal Waihola and Waipori Lake complex is a remnant of the marine inlet.

**Otago Peninsula:** To the east, Dunedin City is bounded on the Pacific Ocean coast by the Otago Peninsula, the heavily eroded remnant of the southeast rim of the Dunedin Volcano. While formed of the same materials as the land underlying the city, the Peninsula also bears limestone deposits which were mined from the 1860s for use in cement making and agriculture. Many lime kilns remain in various states of preservation. Lime production moved to Milburn around the turn of the 20th century where a railway line was available. New Zealand Cement Holdings handed over a kiln and associated quarry to the Otago Peninsula Trust in 1976.

**South to the Clutha:** South of the Peninsula and the city beaches of St Kilda and St Clair, a long coastline broken by headlands at Brighton, Blackhead and Bruce Rocks extends to the Clutha District boundary. The lagoons formed by the Kaikorai and Taieri Rivers further define the southern coastal area with the deeply eroded sandstone cliff at Tunnel Beach offering a distinct contrast to the basalt formations at nearby Blackhead.