

## **Regional Karst Geology**

### **Mary Traves**

On the West Coast of the South Island all karst areas lie west of the Alpine Fault and apart from one small area of Paleozoic limestone (late Cambrian – Ordovician Mt Arthur Group), which has been metamorphosed to marble, this karst is formed from mid Tertiary aged limestones. A small area of fossiliferous Paleozoic Limestone near Reefton (Devonian Reefton Group) is significant to New Zealand's geological history, but not karst forming.

The Alpine Fault is a major New Zealand geological feature which marks the convergence of two active continental plates, the Australasian Plate and the Pacific Plate. Convergence at the boundary between these two plates began around 50 million years ago and continues to this day, with movement on the fault being strike-slip, i.e. there is both vertical uplift (forming today's Southern Alps) and horizontal slip (northward). Scientists estimate that the next Alpine Fault earthquake (probability high in our lifetime) will generate sufficient energy (Force 8+ on the Richter Scale) to cause 1 - 3m of uplift and 7 - 8m of horizontal movement.

Over the Tertiary period this strike-slip movement has separated large blocks of rock which used to be continuous across the fault. The Red Hills ultramafic area in South Westland and the allied Dun Mountain ultramafic area near Nelson are now 480 kilometres apart while the marbles of Mt Arthur are linked to the many marble remnants found throughout Fiordland.

During the Oligocene - Miocene period most of New Zealand was under the sea and large beds of carbonate sediments were laid down, blanketing older sediments and Paleozoic basement rocks. The carbonate sediments eventually became limestones and mudstones which have been since exposed due to upthrust along the Alpine Fault. This mountain building phase, the "Kaikoura Orogeny" began some 20 million years ago and continues down to the present day.

Currently the mountains in and around Mt Cook are "growing" at 10mm per year. But they are also eroding at much the same rate so that on

the coastal shelf there are large depths of recently eroded sediments, plus earlier glacial gravels, overlying large areas of carbonate rocks. As the non-marine coal-bearing sediments under the carbonate rocks have the potential to contain gas and oil, much of the coastal shelf off the West Coast was explored by petroleum companies in the 1960-70s using seismic reflecting methods. The limestones in particular are good seismic reflectors and have contributed greatly to our current understanding of West Coast bathymetry.

The 600 kilometre coastal strip from Kahurangi Point in the north to Big Bay in the south, otherwise known as the "West Coast," is underpinned by some of New Zealand's oldest rocks. These basement rocks are Paleozoic remnants from proto-New Zealand, when this country, along with eastern Australia and Antarctica, formed the southwest segment of Gondwanaland. They are formed from either late Cambrian – Ordovician gneiss (Victoria Paragneiss, Pecksniff Sedimentary Gneiss, Charleston Gneiss) or from a sandstone – shale formation of the same period, commonly known as greywacke (Greenland Group Rocks) or from a late Devonian - early Carboniferous biotite granitoid rock (the Karamea Granites) which was intruded over a wide area. Extensive outcrops of basement rock, from which overlying sediments, including limestones, have been eroded, still exist as the granite - gneiss Papanui and Victoria Ranges, whilst small exposures of all three types can be found along the coast.

The only Paleozoic karst found on the West Coast is a small area at Springs Junction. Here the Sluice Box Limestone formation forms the southern most known outlier of the Mt Arthur Group which includes marble. The "Sluicebox," is a short gorge lying immediately west of the Alpine Fault which has been carved through the marble by the Maruia River. The well decorated Guillotine (or Hunters) Cave can be found in this formation a short distance from Springs Junction.

In some places mid-Tertiary limestones lie unconformably over basement rocks – for instance pockets of Oligocene age Takaka

Limestone in Kahurangi National Park rest on an ancient peneplain formed of Karamea Granites – but in most places there other Mesozoic – early Tertiary sediments in between. These include breccias (mid Cretaceous Hawkes Crag Breccia), coal measures (late Cretaceous Paparoa Coal Measures and Eocene Brunner Coal Measures), sandstones (Eocene Island Sandstone:) and mudstones (early Oligocene Kaiata Mudstone). The Oligocene Limestones are in turn topped in many places by various Miocene formations such as the Welsh Formation (calcareous mudstones and limestones) and Stillwater Mudstone (often known as Blue Bottom or simply “papa”).

The final cap which lies over much of the lowland West Coast landscape, is a layer of Pliocene non-marine gravels (Old Man Formation) and Quaternary glacial gravels. In many places relatively recent Tectonic activity has uplifted the beaches to form raised beaches or terraces behind the present coastline. In some places gravels on these terraces lies directly over limestone, e.g. at Darkies Terrace, Point Elizabeth. Sluicing these gravels for gold was difficult due to the propensity for water to drain away underground from dams and water-races.

With the exception of a very small area of strongly foramineral late Paleocene limestone in South Westland (the Abbey Limestone Formation at Abbey Rocks, south of the Paringa River), the remaining limestones of the West Coast region have been formed during the Oligocene period between 37 and 25 million years ago. They are all considered to be sufficiently similar in age and structure to be placed in the one group, the Nile Group. Outcrops of Nile Group limestones increase from south to north as the gap between the coast and the Alpine Fault widens, i.e. there is far more limestone and consequently more karst and caves north of the Taramakau River than south. In fact there is a large gap to the south synonymous with the “Beech Gap” (Taramakau River to Paringa River) where there are only two minor outcrops. Further south limestone is only found at the coast and on offshore islands.

North of the Taramakau the best karst and caves are formed in Potikohua Limestone which is found, in varying thicknesses, from Fox River to the Punakaiki River. It overlies a

less calcareous, more sandy formation, the Tiropahi Limestone. Potikohua Limestone is formed from a hard white flaggy polyzoan biosparite which averages 90% CaCO<sub>3</sub>. Most of the karst and caves formed in Potikohua Limestone are now protected within Paparoa National Park .

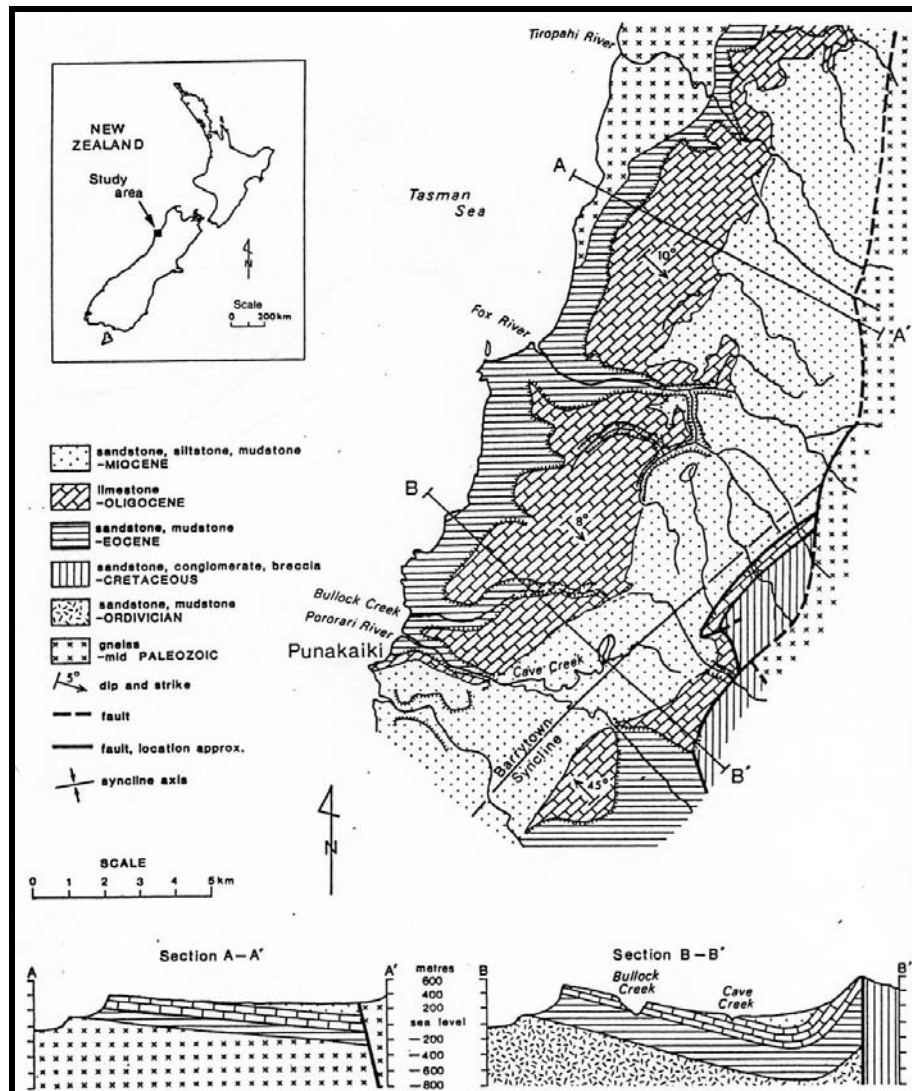
All the other formations are more variable, often with muddier bands grading down to actual mudstone, and of variable thickness. The Tarapuhi Limestone Member, which forms the Point Elizabeth area, is the best ranked (highest CaCO<sub>3</sub>) of the Cobden Limestone Formation while well decorated caves can be found in Takaka Limestone (Megamania), Stony Creek Limestone (Honeycomb) and the Jackson Formation (Serendipity). Caves have also formed in locally highly calcareous Island Sandstone near Rapahoe (Cavern Cave).

The temperate and humid West Coast climate with a mean annual temperature of 12 deg C and mean rainfall at the coast of 2500mm (and more inland in many places) is conducive to relatively rapid karst formation in the Nile Group limestones. Most karst areas are heavily vegetated with either mixed podocarp – beech forest or coastal forest. This makes prospecting for new caves and trips to known ones off the beaten track, hard work. Given that since 1989 when the last ACKMA Conference was held on the West Coast, at least three major new caves have been found (Megamania, Abyssinia and Te Ana Puta), there are probably many more out there waiting to be found.

### **Maps**

No one geological map adequately shows all the karst and cave areas of the West Coast Region. The best is the 1:100,000 Geological Map of the South Island, however the scale is necessarily small. Larger scale maps are available but no one complete series covers all the West Coast. Therefore the maps references for the following work vary from one area to another. The old DSIR 1:250,000 maps are being superseded gradually by the new Q Series maps at the same scale but 1:63,630 (inch to the mile) maps are all that is available for much of the West Coast. An exception is the 1:50,000 Kumara – Moana Geological Map which details the Cobden Limestone very well. A selection of geological maps will be available at the conference.

Map (showing most of the karst within Paparoa National Park)



Map taken from p.11, The Hydrological Behaviour of a High Flooding Frequency Karst System in New Zealand courtesy Scott Crawford, Dept. of Geography, University of Auckland, 1987.

**Some significant Limestone formations in the Nile Group are: (north to south)**

Area	Formation	Example Karst Feature/s
Heaphy	Takaka Limestone	Megamania Cave, Heaphy Bluff
Oparara	Stony Creek Limestone	Honeycomb Hill Cave, Fenian Caves
Murchison	Matiri Formation	100 and 1000 Acre Plateaus
Inangahua Junction	Whitecliffs Formation	Profanity Cave, Damnation Cave
Cape Foulwind	Waitakere Limestone	Rock quarry for cement making
Charleston		Metro Cave, Te Tahī Cave
to	Potikohua Limestone	Fox River Cave, Babylon Cave
Punakaiki		Pancake Rocks, Xanadu Cave system
Greymouth	Cobden Limestone	Grey River Gorge, Te Ana Puta Cave
Jackson's Bay	Jackson Formation	Serendipity Cave, Jackson Head

NB A more comprehensive list of West Coast cave and karst areas is available on the database, *Calcareous Rocks West of the Alpine Fault, New Zealand* by M Traves, 2005. [below]

## Calcareous Rocks West of the Alpine Fault

### PALEOZOIC

#### ***Cambrian- Ordovician***

<b>Formation</b>	<b>Age</b>	<b>Description</b>	<b>Area Found</b>	<b>Feature Points</b>	<b>Other information or / and Issues</b>	<b>Management</b>
Sluice Box L/S	Late Camb. to mid Ordovician	Sluice Box L/S is part of the Mt Arthur Group and corresponds to the Arthur Marble 1 and Summit Limestone of Nth West Nelson.  It is composed of mainly recrystallised grey l/s and siliceous l/s. Sufficient conodonts, trilobites & brachiopods have been found to indicate the age given above	Springs Junction	The Sluicebox  Guillotine (or Hunters) Cave  Outcrops of marble visible from the road	A gorge cut through the marble by the Maruia R.  Abseil entry, pretty cave  One outcrop very near SJ has been quarried  Marble not fully explored for caves	DOC  On private land owned by John Hunter  ??

#### ***Devonian***

<b>Formation</b>	<b>Age</b>	<b>Description</b>	<b>Area Found</b>	<b>Feature Points</b>	<b>Other information or / and Issues</b>	<b>Management</b>
Reefton Group		Exists only as five small outliers of rock overlying Greenland Gp. rocks. Allied to similar small group of rocks at Baton River. Within the five outliers eleven different units have been found including limestone, sandstone and mudstone (shale). Reefton Grp limestones and mudstones contain shelly fossils of Early Devonian age.	Reefton	Former quarries of Stony Creek  Roadside cutting about 1.5kms south east Reefton  Trackside cuttings and outcrops near old coal mines up Lankey Creek Track	The fauna in the limestone and mudstone here and at Baton R (Nth West Nelson) are NZ's only known Devonian period rocks and are therefore important geologically  NB Best seen on road side, up Lankey Ck Track or across Inanaghua R.	Transit (roadsides)  Lankey - Murray Ck Tracks area - DOC  Rainy Creek - private land and DOC

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**MESOZOIC**

No significant  
 calcareous rock  
 strata known

**[NOTE:** very few Triassic - Jurassic rocks are known from West Coast. However the Cretaceous was a significant period.  
 Early Cretaceous: further intrusions of granitoid rocks form significant part of the Karamea Batholith in the Paparoa, Victoria  
 and Hohonu Ranges (over which Tertiary Karst was laid down) plus there are large area of Porarari Group sediments such as Hawks Crag Breccia. In the Late Cretaceous through to the Paleocene the Paparoa Coal Measure were laid down followed in the Eocene by the more extensive Brunner Coal Measures (see below)

**TERTIARY**

**Paleocene**

Formation	Age	Description	Area Found	Feature Points	Other information or / and Issues	Management
Kaipo Slip Marble	Paleocene	Marble found in association	8 miles ntheast	Marble (little detail	Minimal info. Ref. Vol II Geology of NZ, Suggate Very remote area.	DOC
	<i>Dannevirke</i>	with basalt, granite and mylonite with the Alpine Fault zone	Milford Sound	available		
	<b>OR</b>					
	Oligocene	ID from planktonic foraminifera				
	<i>Landon</i>	give only late Cret/early Tertiary age.				
Abbey Rocks L/S	Paleocene	Hard impure blue-grey to white	Tititira Head to	Rock was quarried on-	Former quarry area only acquired from private ownership mid 90's. Very remote location. Rock atypical for WC: similar rock found only in Marlborough and Nth Is.	DOC
	to early Eocene	muddy limestone, fine grained. and foraminiferal	Abbey Rocks (Sth Westland)	shore opposite Abbey R. 1876 - 1906 for lithological stone. Samples sent to exhibitions in Melbourne and Chch. Quarry not economic.		
	<i>Waipawan</i>					
	<i>to Runangan</i>					

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 Proceedings of the 16th ACKMA Conference, Westport, NZ, 2005*

**Eocene**

<b>Formation</b>	<b>Age</b>	<b>Description</b>	<b>Area Found</b>	<b>Feature Points</b>	<b>Other information or / and Issues</b>	<b>Management</b>
Island Sandstone	Eocene <i>Kaiatian to Wha</i>	This formation is extensive on the West Coast, overlying the Brunner Coals and underlying much of the limestone from the Grey R. northward to the Nile R. It consists of brown- grey fine to very fine muddy calcareous sandstone. CaCO3 levels vary widely anywhere from 20 - 60% and locally even more where it is cavernously forming.  <i>Carbonate factor in this rock has capacity, in part, to offset effects of acid mine drainage from mining Brunner coals</i>	Perpendicular Point	The Te Miko Cliffs at Perpendicular Point	Much photographed from Irimawhero Point	DOC Private land
			Truman Track	Visually attractive	Popular tourist track -	DOC
			coastline	coastline sculpted by elements. Includes sea-caves, cliffs, overhangs	Some northern caves are Maori Archeo. Sites	NZ Archaeo. Society
			Rapahoe Area	Cavern Cave and other small caves between Rapahoe and Dunollie	Cavern Cave used by Wild West for cave concession Potential destruction of cave from coalmining	Min of Eco. Develop. Crown Minerals licence held by Solid Energy, Spring Ck Mine
			Mussell Pt (Eight Mile Bluff) near Rapahoe	Seacliff coalmines, shag nests, sculpted coastal area	DOC & WCRC	

**Oligocene**

<b>Formation</b>	<b>Age</b>	<b>Description</b>	<b>Area Found</b>	<b>Feature Points</b>	<b>Other information or / and Issues</b>	<b>Management</b>
Takaka L/S	Oligocene <i>Waitakian</i>	Hard, crystalline but apt to be sandy in lower half of the 30 - 35m thick formation Forms prominent escarpments and caves.	Heaphy Track	Megamania Cave Other Heaphy Caves Prominent coastal out-crops - Kahurangi Pt, Heaphy, Kohaihai Bluffs	Megamania Cave recent discovery. Major cave system / archeo site, protected, permit required	DOC KNP

*Cave and Karst Management in Australasia 16  
 Proceedings of the 16th ACKMA Conference, Westport, NZ, 2005*

<b>Oligocene Formation</b>	<i>(continued)</i> <b>Age</b>	<b>Description</b>	<b>Area Found</b>	<b>Feature Points</b>	<b>Other information or / and Issues</b>	<b>Management</b>
Stony Ck L/S	Oligocene	Wedge of poorly bedded L/S up to 85m thick lie unconformably over Karamea Granite. Many macrofossils (molluscs, coral) present and overlain by Miocene mudstone. High rainfall and cutting down of Oparara River have contributed to rapid development of these caves	Oparara	Honeycomb Hill Caves Oparara River Limestone Arches	Major NZ heritage area. Selected areas developed for visitors and remainder gated, access by permit One of two habitats of NZ's largest spider, <i>(Spelungla)</i>	DOC
			Fenian	Fenian Basin and Caves	Caves area access via Fenian Trk up Oparara R. Also an old gold diggings.	DOC
Karamea Bluff L/S	Oligocene <i>Wha - Wai</i>	Variable strata ranging from thick bedded light grey to muddy l/s locally bedded with grey calc. m/s to massive light grey to light brown calcareous m/s. Some mudstones containing debris flow sandstones or breccia	Little Wanganui (inland)	Black Rat Mountain	CaCO3 samples average over 95% (1910)	Private Land around Deep Creek and Corbyvale
			Coast between Little Wanganui & Gentle Annie	Whitecliffs Kongahu Point The Wineglass (slip) Gentle Annie Point	Major slumping of cliffs due to 1929 EQ. Wineglass slip can be seen from out to sea	Otherwise DOC
			Six Mile Creek	Caves/underground drainage (above WineG.)	Area needs prospecting	

*Cave and Karst Management in Australasia 16  
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<b>Oligocene Formation</b>	<i>(continued)</i> <b>Age</b>	<b>Description</b>	<b>Area Found</b>	<b>Feature Points</b>	<b>Other information or / and Issues</b>	<b>Management</b>
Whitecliffs L/S	Oligocene <i>Wha - Wai</i>	Moderately extensive (both sides Buller River) formation forming large escarpment of Berlins Bluff and "Whitecliffs" (by Highway): varies thru' basal conglomeratic limestone to sandy micaceous limestone to calcareous mudstone. Some flaggy organic l/s boulders below Berlins Bluff.	Inangahua Jcn	Profanity Cave Damnation Cave Assorted other smaller caves	Scene of major cave rescue in ?? Some damage/blockage entrances due to 1968 Inangahua Earthquake. Most survey work done by CCG. An area worth further prospecting.	DOC
Iron Bridge L/S	Oligocene <i>probably Dun - Wai</i>	Interbedded white or light-grey algal limestone, impure in places thru' to micaceous mudstone and calcareous sandst.	Iron Bridge (over Buller R.)	Forms prominent 12m. high prow of rock at nth. end bridge. Biddies Cave	Found both sides of river (also minor amount Little Flaxbush L/S).	Access through private farmland
Fletcher Ck. L/S	Oligocene <i>probably Dun - Wai</i>	Hard white flaggy organic l/s locally containing abundant shell fragments: highly calcareous (82-96% CaCO <sub>3</sub> ). A polyzoan or foraminiferal biosparite.	Inangahua R. valley	Forms the upper part of scarp in the vicinity of Fletcher and Mc Murray Creeks on south-west side of Inangahua Valley	In association with opencast coalmining of Brunner Coals (Fletchers and Burleys Opencast Mines)	
Mc Murray Ck L/S	Oligocene <i>Wha - Dun</i>	Light grey or creamy sand l/s locally containing black biotite 15 - 26m thick.	Inangahua R. valley	Forms the lower part of scarp in the vicinity of Fletcher and Mc Murray Creeks on south-west side of Inangahua Valley		



*Cave and Karst Management in Australasia 16  
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<b>Oligocene Formation</b>	<i>(continued)</i> <b>Age</b>	<b>Description</b>	<b>Area Found</b>	<b>Feature Points</b>	<b>Other information or / and Issues</b>	<b>Management</b>
Newton L/S	Oligocene	White very pure (98%) algal limestone	Newton River	Quarry in moderate sized outcrop. Little known caves/karst lie across Buller River, visible from rd.	Used for agricultural and industrial lime	Private quarry Murchison locals have some knowledge of caves
Matiri L/S	Oligocene <i>Wha - Dun</i>	Widespread formation in the Murchison area. Impure, arenaceous limestone overall, higher grades outcrop locally. Forms prominent landforms, and locally, moderate sized caves. Few macrofossils and localised foraminifera give the age at Oligocene extending into Lower Miocene ( <i>Pareora</i> ) near Brewery Ck. Co-relates to Cobden L/S in age	Matiri River	Thousand Acre and One Hundred Acre Plateaus (drain west)	Excellent tramping area. Many sinkholes, well prospected with few leads.	DOC
			Murchison	"Old Man of the Buller" "Sphinx" - both well - known local landforms	Both signposted from highway	DOC Private land
			Maruia Valley	Pea Soup Creek Caves	Gibsons Go Cave access thru' farm/need permission	DOC
			Buller Valley	Newton Creek Quarry	High quality L/S used for quicklime	Privately owned
			<i>[Accessed by swingbridge]</i>	Deepdale/White Creeks (at White Fault)	Reserve sth side river open to public/interpreted	
Waipuna L/S	Oligocene	Pure (mean 94%) creamy - fawn limestone, some places bluish - grey. Shell macrofossils evident.	Clarke River, end of Waipuna Road, Grey	Agricultural Lime Quarry	This remnant of limestone has been on top of a hill. Now half quarried away	Lamplight Mining Co. leased out to Crofts of Stillwater

*Cave and Karst Management in Australasia 16  
 Proceedings of the 16th ACKMA Conference, Westport, NZ, 2005*

<b>Oligocene Formation</b>	<i>continued</i> <b>Age</b>	<b>Description</b>	<b>Area Found</b>	<b>Feature Points</b>	<b>Other information or / and Issues</b>	<b>Management</b>
Waitakere L/S	Oligocene <i>Lwr Wha</i>	<p>Samples have calcite crystals.</p> <p>White to light grey algal limestone [algal biosparite]. Highly calcareous, averages 94%</p> <p>Found north Charleston only</p>	Valley	former caves quarry for cement works	limited resources left for cement works: other sources being sought	Holcim
		<p>Found north Charleston only</p>	Charleston	hard rock quarry agricultural lime quarry	1988 Mc Laughlins Pit - 2 sites	Private
Tiropahi L/S	Oligocene <i>Lwr Wha to Dun.</i>	<p>White to light brown muddy limestone, averaging 68% CaCO<sub>3</sub>. Impure foraminiferal biomicrite. Overlies Waitakere Limestone north of Fox River Found north Hatters Bay only</p>	Nile River (south bank)	Venturer Cave	easy accessible cave used by beginner cavers: impacted by much use	DOC
		<p>White to light brown muddy limestone, averaging 68% CaCO<sub>3</sub>. Impure foraminiferal biomicrite. Overlies Waitakere Limestone north of Fox River Found north Hatters Bay only</p>	Fox River (at coast)	Seal Island - whole island including sea-caves	accessible on foot at spring low tides site of historic coal loading operation former Brighton Mine	DOC
	<p>Sandy component in this formation contains flint</p>	Pahautane (at coast)	Flint (microcrystalline quartz) which has formed in the sandy limestone	Maori Archaeological Site	DOC NZ Archaeo Society	

*Cave and Karst Management in Australasia 16  
 Proceedings of the 16th ACKMA Conference, Westport, NZ, 2005*

**Oligocene  
 Formation**

	<b>Age</b>	<b>Description</b>	<b>Area Found</b>	<b>Feature Points</b>	<b>Other information</b>	<b>Management</b>
Potikohua L/S	Oligocene <i>Dun - Wai</i>	Hard white flaggy limestone (polyzoan biosparite) overlying Tiropahi L/S. Averages 90% CaCO <sub>3</sub> . Extends over a wide area but thickness varies greatly. Cavernously forming	Nile River	Ananui Caves (Metro)	Long gated due to visitor impacts. Permits required. Used for tourism concession and well known for glowworms	DOC  PNP & Nor West Ventures
<b>Forms most significant cave and karst features within Paparoa National Park.</b>			Four Mile Rd Tiropahi River	"Hole in the Wall" Arch Hollywood Cave Te Tahi Cave Alpha Creek Caves	Recreational caver impacts noticeable in popular caves. Limestone sought from this area by Holcim	DOC since 2001
		Aesthetic Qualities	Fox River (inland)	Pink Limestone	Being progressively utilized for stone carving	DOC PNP
		Significant linked systems	Fox River (inland)	Gethsemane (doline), Cave Creek Nth, Babylon & Fox River Caves	Tourists are directed to easy section Fox River Cave as representative cave for area. Noticeable impacts partially mitigated by DOC procedures	DOC PNP
<b>Forms the core of the Punakaiki Anticline and is bisected by the gorges of the Nile, Fox, BullockCk, Porarari and Punakaiki Rivers</b>		Rivers cut down to form gorges	Fox River (inland)	Fox River Gorge The Ballroom Overhang Dilemma Creek Gorge	Very popular campsite for those on Inland Pack Track tramp via gorge	DOC PNP
<b>Two examples of stream capture in area. Cave Ck North - Fox R. Bullock Ck - Cave Ck Sth</b>		Extensive karst drainage	Bullock Creek	Polje and Sinks Stream Capture to Cave Creek South via Xanadu Cave System	Proposed Ramsar site post end farm lease. Tourist concession on Xanadu Cave	DOC PNP  Green Kiwi
		Stylobedded locally along coast	Dolomite Point	Pancake Rocks	Major developed tourist drawcard. Safety issues.	DOC PNP

*Cave and Karst Management in Australasia 16  
Proceedings of the 16th ACKMA Conference, Westport, NZ, 2005*

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Cobden L/S Formation	Oligocene	Extensive limestone area sth. of Paparoa Coalfield and analogous in age to Tertiary L/S further north.	Point Elizabeth (coastal)	Te Ana Puta Cave Off shore seastacks with above/underwater seacaves	Sporty cave, not for beginners in immediate vicinity of a popular walkway.	DOC Rapahoe Range Scenic Reserve
<i>[3 members: Ngarimu L/S Tarapuhi L/S Puketahi M/S]</i>	<i>Wha Dun Wai</i>	Fine-grained creamy-white to light brown-grey muddy micritic limestone, interbedded with bands of calcareous mudstone. CaCO <sub>3</sub> levels average 70-75% but locally can reach 85% (Fireball Ck). A full section of the formation can be seen at Grey R gorge but elsewhere the top two members are more common with the Tarapuhi L/S being cavernously forming. Details of the extent of this formation are particularly well known due to coal & oil drilling. Structure is valued as a seismic reflector by geologists.	Greymouth	Grey River Gorge Tainui (Cobden) Cave Kings Domain Track	Highly modified including quarrying of a Maori burial cave	Grey District Council
<b><i>This formation is notable for the many different land managers it has compared to other parts of the West Coast. Examples are given for each. It is also the only place where karst is within a town boundary</i></b>			Greymouth	Cobden Quarry (north side)	Still in use Moves by locals to landscape and / limit access	West Coast Regional Council
			Greymouth	Toe of Peter Ridge in vicinity of original Mawhera Pa	Owners have allowed unsightly quarrying at toe of Peter Ridge	Mawhera Corporation Ngai Tahu
			Limestone Rd	Saltwater Creek Polje & associated caves	Much modified area. Geologically karst drain is stagnating as it tries to drain across the active Brunner Anticline	DOC and Private landowners
			Marsden	Marsden and Smalls Caves	Caves/karst area modified by goldmining, farming & pine planting/harvesting Unusual fish species reported from Marden C.	Private landowner
			Cape Terrace	Whiskey Cave Fireball Creek Gorge Historic Nicks Cavern SF1 Oil Bore, 1941	Caves damaged by goldmining/timber harvesting. Probable stream capture from Fireball to TanseyCk	Timberlands Exotic Forest (pines)

*Cave and Karst Management in Australasia 16  
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Kowhitirangi L/S	Oligocene Wha - Wai	Hard white locally crystalline, sandy or muddy limestone, glauconitic in places with mudstone and calcareous siltstone bands in places. Non-cavernous and used for quicklime/quarry stone	Kowhitirangi	Mt Camelback including quarry  Outcrops near Kowhitirangi township	Quarried for rock and making quicklime	Top of Mt Camelback under DOC m'ment Hard Rock Quarry - WC Regional Council Lime Quarry - private
Ross L/S	Oligocene Dun - Wai	White crystalline limestone overlying either carbonaceous quartz sandstones or calcareous quartz sandstone/conglomerate Contains foraminifera and polyzoa, fine grained.	Ross	Hodson - Donnelly Cks.	Quarried for rock and making quicklime	Quarry under lease by West Coast Farmers Co-op.Lime Co. from DOC
Jacksons Bay L/S	Oligocene Wha - Wai	Hard white crystalline and laminated limestone. Styolitic laminations probably parallel and on exposed surfaces weather out as sharp fins which are abrasive, particularly so on Open Bay Islands. Thin sections of rock show it to be bioclastic with numerous microfossils	Okuru	Open Bay Islands including sea-caves	Wildlife Refuge (seals & seabirds), Maori land and NZ Archaeo site.	Te Runanga O Maakawhio - Bruce Bay iwi
			Jacksons Bay	Jackson Head Serendipity Cave Large sea-caves	Serendipity is an Maori Archeo. Site. Relics and bones moved to Otago University in 1970's.	DOC stewardship land
			Cascade Coastline	Browne Island Gorge Island Old seacave north side Gorge River	Remote area, no roads. Needs cave prospecting. Many Maori artifacts found south side GorgeR.	DOC South Westland World Heritage Area
Awarua L/S	Oligocene Wha - Wai	Massive crystalline limestone. Long sliver parallel to Alpine Fault	Big Bay	Outcrops on both sides Big Bay, Martins Bay and coast at Kaipo R.	Last limestone found going south before Alpine Fault crosses out to sea	DOC Fiordland NP

*Cave and Karst Management in Australasia 16  
 Proceedings of the 16th ACKMA Conference, Westport, NZ, 2005*

**Miocene**

<b>Formation</b>	<b>Age</b>	<b>Description</b>	<b>Area Found</b>	<b>Feature Points</b>	<b>Other information or / and Issues</b>	<b>Management</b>
Welsh Formation M/S	Miocene <i>Wai. to Altonian</i>	Extensive brown calcareous muddy sandstone. Variable. Overlies the Potikohua L/S at most locations.	Punakaiki	Cassies, Toblerone & other small caves (in conjunction with Razorback Formation)	Little known muddy caves in heavily vegetated, difficult terrain	DOC PNP
		The Razorback Limestone Member forms a lens within the Welsh Formation in the Punakaiki River area.	Punakaiki River	The "Razorback" headland and seacaves	Well visited/well known popular coastal interest place	DOC