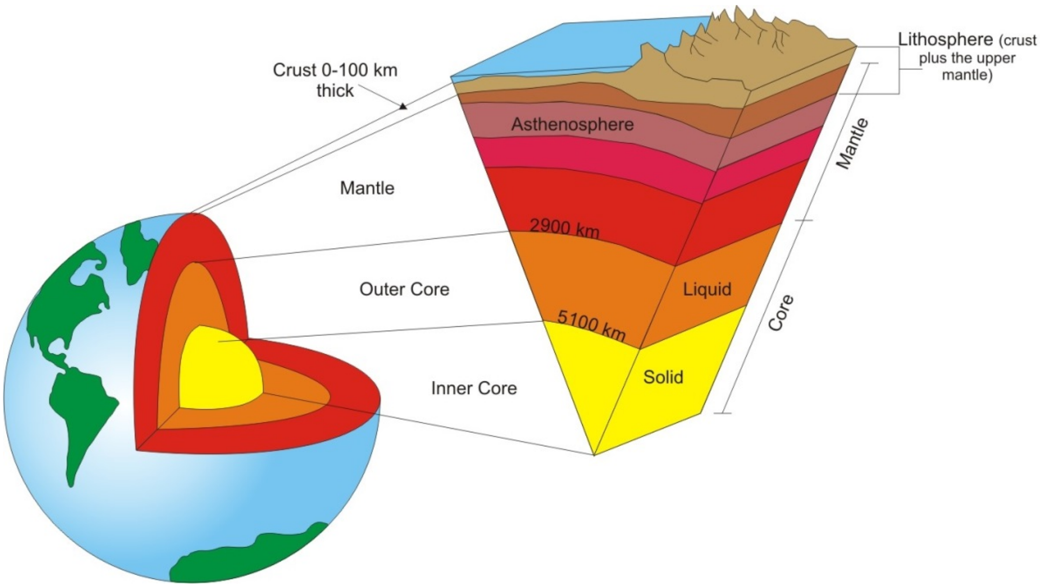
Geology of the Bega Valley Shire

Mick Harewood, October 2019

Introduction.

I have not undertaken any formal study of geology at a tertiary level, except as a small element of soil science. I majored in Biochemistry and Genetics for a BSc degree. My interest in geology has been through a general interest in the local environment and a particular interest in hydrology.

Structure of the Earth



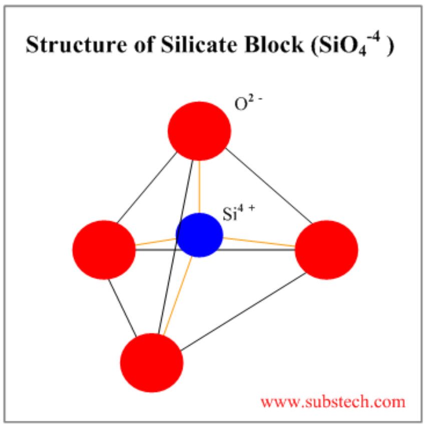
The Earth's core is made up of iron and nickel, mostly molten but the central core is so dense it is solid. Flow of molten iron around the centre is thought to generate the earth's magnetic field.

The mantle consists of hot rock, so hot that it is plastic.

The crust represents about 1% of the total volume of the earth. The oceanic crust is relatively thin and consists mainly of basalt. The continental crust is thicker and consists mainly of granite and sedimentary rocks.

The oceans are an average of 5.8 km deep and 90% of the earth's atmosphere is in the first 10 Km.

The most common minerals in the earth's crust are silicates (SiO4). Silicon is in the same column of the periodic table of elements as carbon, so it tends to form 4 covalent bonds arranged as a tetrahedron.

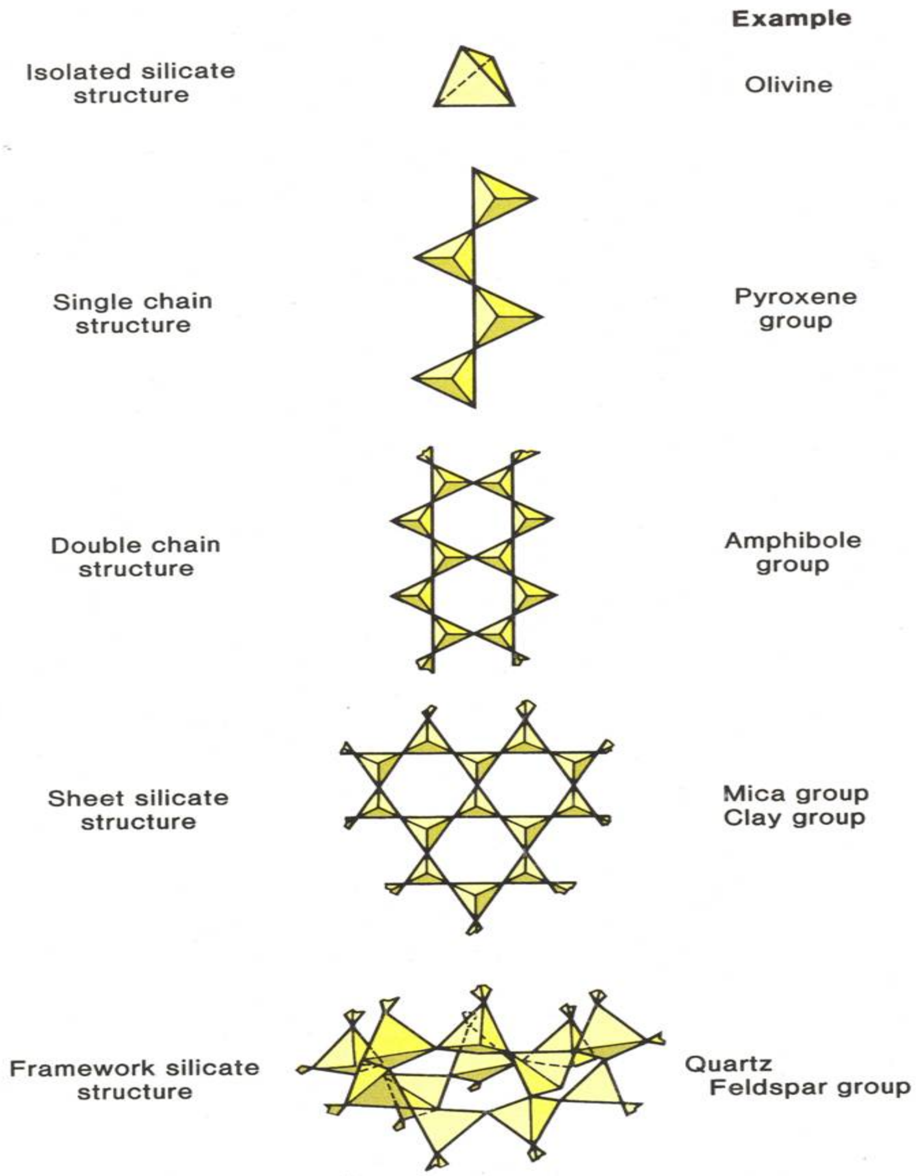


Both carbon and silicon are said to have a valency of 4, that is, they form more stable chemical compounds when they are sharing 4 electron pairs. This gives silicates the ability to form relatively stable linear strings, hexagonal rings and planar structures resembling chicken wire.

There are clear analogies between carbon and silicate molecular structures. Graphite is extensive planar sheets of pure carbon rings. It is the lead in lead pencils, so when we draw with a pencil, sheets of pure black graphite are left on the paper. Finely ground, it can absorb pollutants like chlorine between the sheets.

Sheets of planar silicates form clay minerals. They absorb water and expand in volume as they do so.

Three dimensional carbon crystals we call diamonds. Three dimensional silicate crystals we call quartz.



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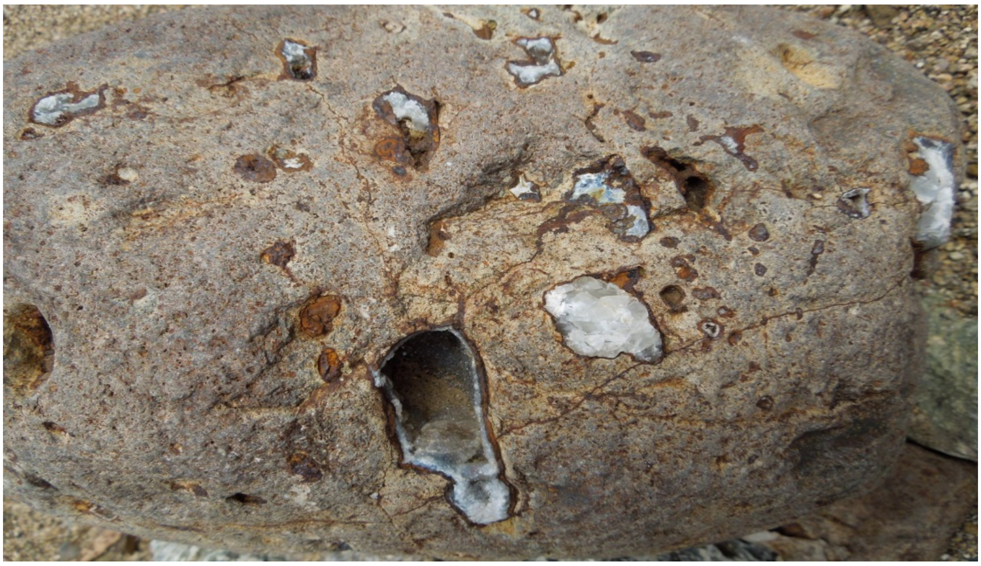
Types of rock.

At high-school, we learned that there are three types of rock, igneous, sedimentary and metamorphic. These distinctions are somewhat blurred as will be explained.

Igneous rocks are volcanic in origin, that is, they are extruded as molten magma from under the crust. If they cool quickly the crystal structures tend to be smaller as in basalt. Granite is also an igneous rock but it is silica-rich because it incorporates molten rocks from the base of the earth's crust. The crystals of granite are larger because it has cooled slowly under pressure. Rhyolite or pink granite is also silica-rich and forms poorer or skeletal soils.



Sedimentary rocks include limestones and sandstones, silts, mudstones etcetera. Limestone consists of calcium carbonate and is derived from the exoskeletons of marine organisms. All sedimentary rocks were once laid down in horizontal strata at the bottom of lakes, rivers, estuaries or seas.

Metamorphic rocks are sedimentary rocks that have been changed over time by compression, heat, distortion or other processes. They include the Ordovician metasediments of some of our coastal forests and the spectacular Devonian Merimbula mudstone seen in places along the coast.

Geological Ages

The earth is thought to be about 4.6 billion years old. Simple life forms did not appear until near the end of the Precambrian era. Life on the land did not appear until after the Ordovician in the Palaeozoic era. The dinosaurs did not evolve until the Mesozoic era.

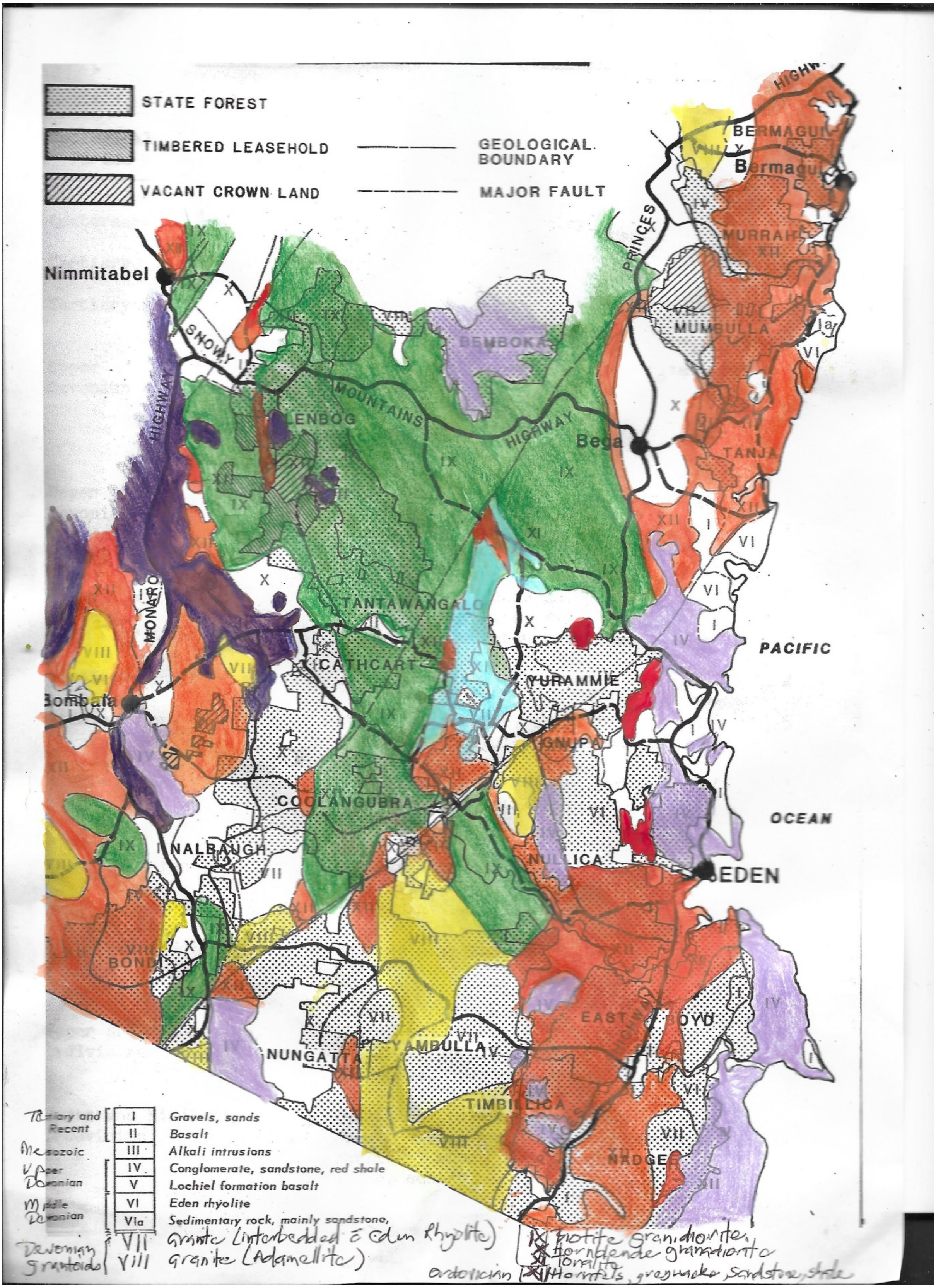
Geological Time Scale

ERA	PERIOD	EPOCH / AGE	Million Years Ago	EVENTS
CENOZOIC *Age of Mammals* 65.5 mya – present day	*Quaternary*	*Holocene*	*Today*	Ice Age ends Humans are dominant
		Pleistocene	*0.01*	Earliest Humans appear Ice Age begins
	Tertiary	*Pliocene*	*1.6*	Hominids (human ancestors) appear
		Miocene	*5.3*	Grass becomes widespread
		Oligocene	*23.7*	Mammals are dominant
		Eocene	*36.6*	Eocene – Oligocene extinction event
		Paleocene	*57.8*	First large mammals appear
MESOZOIC *Age of Reptiles* 245 mya – 65.5 mya	*Cretaceous*	*Extinction of Dinosaurs*	*65.5*	K-T extinction event Earth looks closer to present-day Flowering plants appear
	Jurassic		*144*	First Birds appear Pangaea splits into Laurasia, Gondwanna Dinosaurs are dominant
	Triassic	*First Dinosaurs*	*208*	Pangaea cracks First mammals appear Reptiles are dominant
PALEOZOIC 570 mya – 245 mya	*Permian*	*Age of Amphibians*	*245*	Permian – Triassic extinction event Pangaea forms
	Carboniferous		*286*	First reptiles appear First large cartilaginous fishes appear
	Devonian	*Age of Fishes*	*360*	Late Devonian extinction event First land animals appear First amphibians appear
	Silurian		*408*	First land plants appear First jawed fishes appear First insects appear
	Ordovician	*Age of Invertebrates*	*438*	Ordovician – Silurian extinction event First vertebrates appear
	Cambrian		*505*	End Botomian extinction event First fungi appear Trilobites are dominant
PRECAMBRIAN 4600 mya – 570 mya	*Proterozoic Eon*		*570*	First soft-bodied animals appear First multicellular life appear
	Achean Eon		*2500*	Photosynthesizing cyanobacteria appear First unicellular life appear
	Hadean Eon	*Priscoan Period*	*3800* *4600*	Atmosphere and oceans form Oldest rocks form as Earth cools
Formation of Earth				

"One way to grasp the magnitude of geological time is to compare it to the events in a year, to compress the entire 4.6 billion years into 365 days. On that scale, the oldest minerals we can date formed in mid-January and we can find living creatures such as algae and bacteria in May. Plants, then animal did not emerge on land until the end of November, and the "valuable" coal basins of eastern Australia were formed from vast peat lands over a period of 19 hours on 10 December. Dinosaurs roamed central Queensland from shortly after this until 26 December, when Australia separated from Antarctica and started its drift northwards towards Asia. The great barrier reef probably formed mainly after 11.03 pm on 31 December. Aboriginal people arrived perhaps around 11.54 pm and the last of the giant kangaroos died out by 11.59.35. Rome ruled the Western world for 5 seconds from 11.59.50 to 11.59.55. James Cook arrived on the Australian coast at 1 second to midnight. And, as they say, the rest is history."

Local Geology.

This map of local geology is derived from a report by Beams and Hough which appeared in the Eden Native Forest Management Plan 1982 (SFNSW May 1983).



Some key features are as follows.

<u>Ordovician metasediments</u>.

These are mainly shales, siltstones and mudstones laid down in lakes and seas at a time when there was unmitigated erosion due to the absence of complex life on the land. The strata were once horizontal but folding and movement of the earth's crust over 444 million years has meant that they are now pretty well anything but horizontal. Near-vertical fissures allow the deep penetration of water so that the surface is rarely properly wetted.

Soil forming processes can only occur when there is warmth and moisture at the soil surface, allowing plant-growth and litter decomposition. Ordovician metasediments tend to only form skeletal soils which are often hydrophobic. However, large trees such as Eucalypts can grow well on these sites due to the ability of their roots to follow the fissures down to seek out water at depth.

These landscapes tend to have a high drainage density because most of the runoff is stormflow through sub-surface fissures. Drainage density is the number of gullies or drainage lines per square kilometre. Gullies tend to be actively incising.

The Bega Batholithe.

The Bega Valley is dominated by decomposed granite soils, mainly derived from a type of granite called biotite granodiorite. This forms relatively fertile soils with a good cation exchange capacity.

Cation exchange capacity is a rough proxy for soil fertility. (Tulau 1997). When the type of clay in a soil has low cation exchange capacity, it tends to form an amorphous mass when wet and when it dries out, it becomes like a hardened brick with large cracks. Divalent cations such as Calcium and Magnesium can bind reversibly to clays with a higher cation exchange capacity to form aggregates or crumbs. These generally have a size of 2 to5 mm and allow the soil to breathe and water to permeate, even when the soil is fully wetted up or relatively dry. These clays can also readily exchange important plant nutrients such as Potassium, Calcium, Iron and some forms of nitrogen.

Exposed granite boulders can be seen throughout the valley, depending on local topography. Rainfall distribution throughout the year is the main limitation on plant growth. Decomposed granite soils are quite porous so they are subject to erosion along exposed road cuttings and streambanks.

Adamellite granite

This type of granite forms very poor soils. There is no Phosphorus in the parent rock. Particle size in the surface soil tends to be quite coarse, with clay leached to a subsurface layer (i.e. a Podzol). Areas of adamellite have generally not been selected for agriculture and support low commercial quality forests. However, the clay layers below the surface in a podzol can slow the drainage of rainfall and help to form biodiverse heath swamps.

Basalt.

There are important intrusions of basalt in Glenbog, the Nethercote/Lochiel region and in parts of the Towamba Valley such as the acid-basalt at Pericoe and some basalt capping in the Coolangubra forest as well as the Golan Head area on the coast south of Bermagui. These date from the Devonian and Quaternary eras.

Basalt forms some of the most fertile soils, with a high mineral content, amazing moisture holding capacity and a generally excellent crumb structure. These are known as Kraznozems. It is no surprise that areas of basalt intrusion have commonly been cleared of the rich forest they once supported and selected for agriculture.

Volcanic ash has contributed to a thin layer of richer topsoil in some areas, over less fertile geologies. These areas, cleared of their original tall forest, can be subject to tunnel erosion.

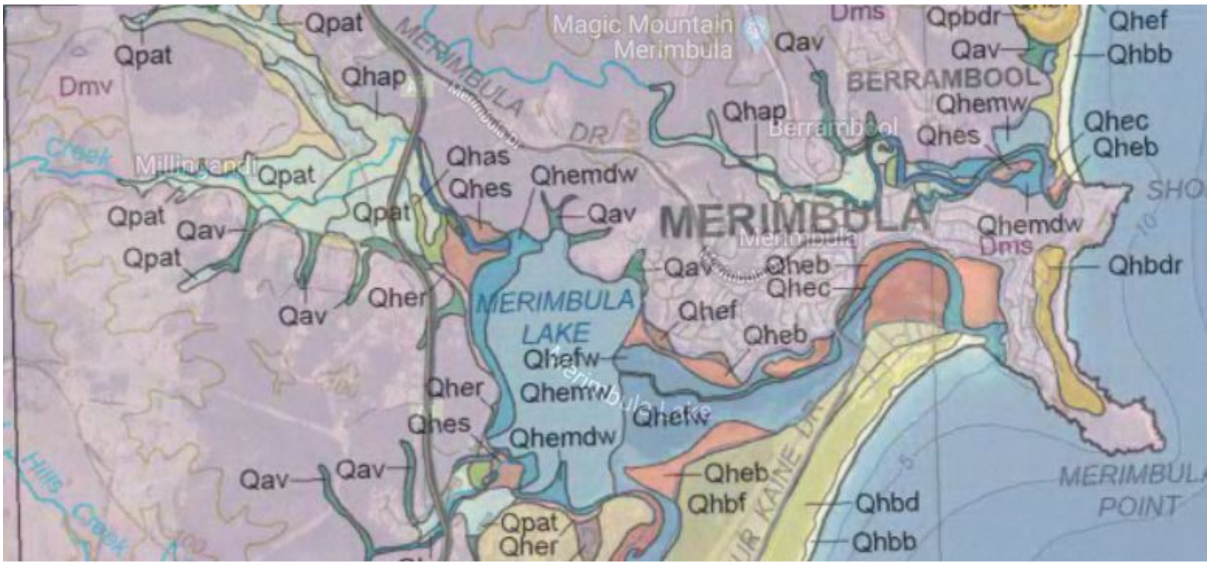
Devonian and Silurian metasediments.

These geologies are common along the coast of the Bega Valley shire. They include the spectacular red mudstone seen along the coast at Merimbula, Pambula River Mouth, Haycock Point and far into Ben Boyd South National Park at places such as Mowara. This metamorphic rock was originally the bed of a Mississippi-sized river that flowed from the McDonald Ranges region to the Gondwana coast.

Devonian and Silurian sandstones, shales, siltstones and conglomerates do not generally form particularly fertile soils. They are often overlaid with windblown sand (known as Aeolian sand) or alluvial material in valleys.

Local surface geologies.

These images of local surface geologies can be searched via google maps with a geology overlay.



Most of the Merimbula environs is known as Dms (purple on this map) or Devonian meta-sediments, in purple. These are generally hard, stable rocks which form relatively skeletal soils. They support forests because tree roots can penetrate deep fissures to access subsurface moisture.

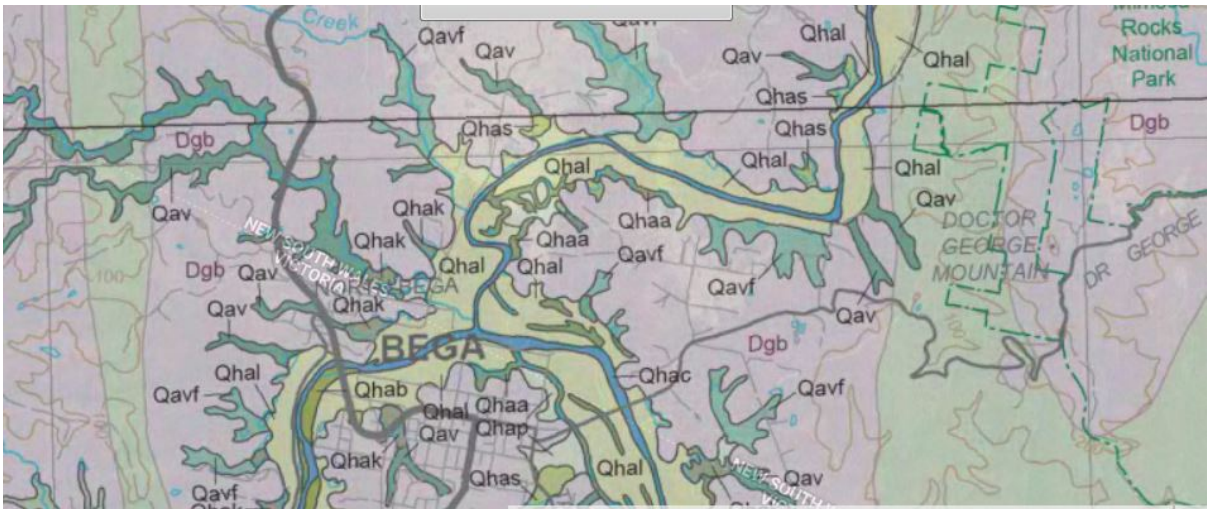
Dmv (purple) signifies Devonian volcanic rocks. Basalt capping in the Bald Hills area gave these surface soils much greater fertility due to both mineral content and soil structure. These areas supported taller forest and were cleared early on for agriculture. However, they can be subject to tunnel erosion where the surface soil is richer and better-structured than the subsoil derived from different material.

Qpat (pale green), around the Millingandi floodplains, signifies Pleistocene terrace, of silt, clay, fluvial sand and gravel.

Qheb (orange) is Holocene estuarine in-channel bar and beach: marine sand, silt, clay, shell, gravel

Qhbd (yellow –green) is Holocene dune of marine sand.

The Bega local environment is dominated by granite.



Dgb (purple) is Devonian intrusive rocks. Here it is the biotite granodiorite of the Bega batholithe. It forms a rich black loam with high cation exchange capacity and relatively high permeability. It is the basis of the successful local dairy industry in spite of a relatively erratic rainfall distribution.

There are bands of Ordovician metasediments to the west and east of Bega. Remember metasediments from the Ordovician era formed before there was complex life on the land. They were once horizontal but are now anything but.

Qhal (pale green) is Holocene levee: fluvial sand, silt and clay

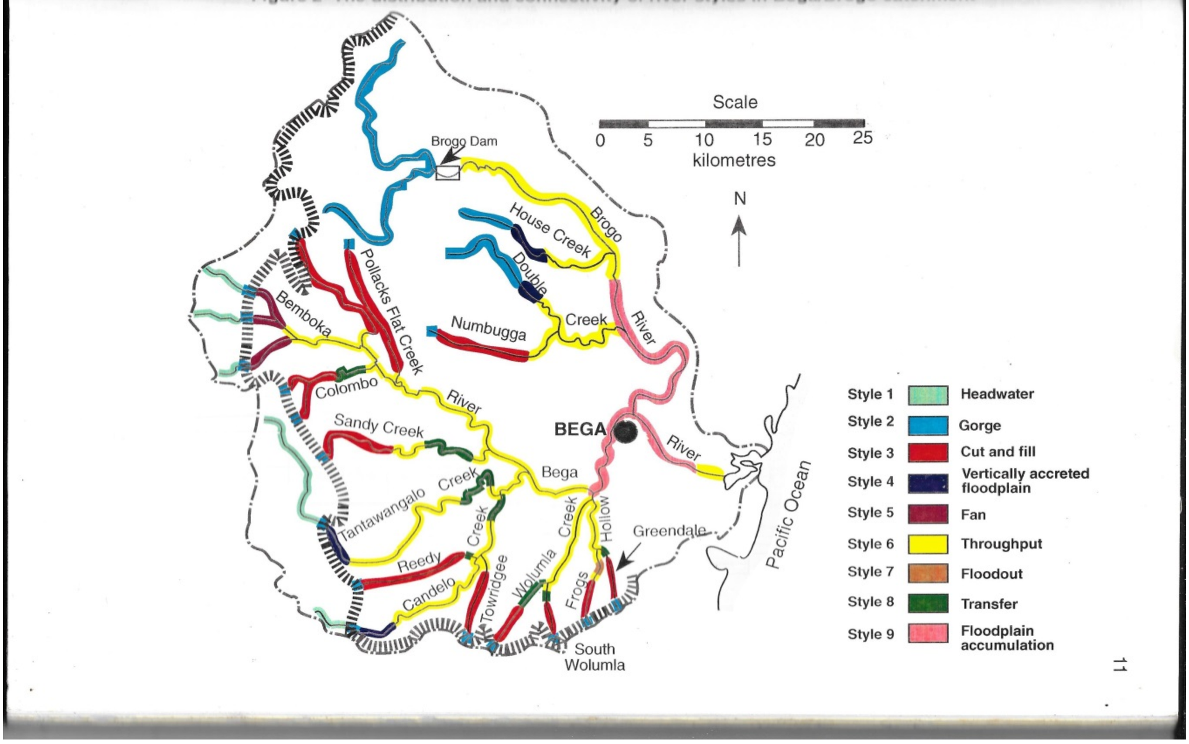
Qhab (leaf green) is Holocene in-channel bar: fluvial sand gravel silt clay

Qhav (emerald green) is Quaternary undifferentiated valley fill: silt, clay, fluvial sand, gravel.

This brings us to a consideration of the fluvial geomorphology of the Bega Valley.

Krystie Fryirs, a PhD student of Professor Gary Brierley of Macquarie University, compiled a sediment budget for the Bega Catchment. In brief, she found that, since European settlement, 21.7 million cubic meters of bedload sediments has been eroded, mainly from sedge and tea tree swamps at the foot of the escarpment. These areas were cleared to grow crops, mainly corn. When intensive rainfall events inevitably occurred, the cleared swamps incised and eroded away, putting more erosive pressure on the banks downstream.

Figure 2 The distribution and connectivity of river styles in Bega/Brogo catchment



Overall 11% of the 21.7 million cubic meters of bedload sediment has gone out to sea, about half in in the Bega Sands Aquifer and the rest is in transit.

In-stream swamps are a bit like melting snowfields in that they store water from wet times and release it slowly to maintain a good baseflow in rivers. Their loss means that low flows are even lower, which has impacts on the fish and aquatic invertebrates, as well as economic impacts.

Continental Drift.

So far I haven't touched on Continental drift or plate tectonics. The idea that continents can drift over the surface of the earth seems bizarre, but the evidence is overwhelming. As early as 1915, Alfred Wegener noted that the same fossil species could be found on different continents, far apart. The shapes of contemporary land masses can be fitted together, rather neatly like a jigsaw puzzle. The mid-ocean volcanic ridges seem to be pushing the tectonic plates apart. Satellite tracking has proven that the continents are still moving. In fact, Australia is moving to the north at 67mm per year.

Very long term continental drift has driven very long term climate change over millions of years. Continents have changed latitude and ocean currents have been massively impacted. Given that the oceans represent 99.9% of the heat capacity of the earth's climate system, it is no surprise that changes in ocean currents have a major effect on continental climates. For example, Australia started to separate from Antarctica about 84 million years ago and this allowed for the southern circumpolar current to gradually intensify. Antarctica cooled to become a massive ice-cap.

Short-term climate cycles can be mainly explained by astronomical cycles of around 100,000 years. These are the so-called Milankovic cycles and they relate to the elliptical nature of the earth's orbit around the sun, the changes in the angle of the earth's rotation relative to the plane of the orbit, and the precession of the axis of rotation relative to the orbit. Note that this has only driven the development of ice-ages once the northern hemisphere has had a preponderance of land in appropriate latitudes. A gradual cooling causes the formation of ice and snow over the large northern land masses of Siberia, Europe and Canada. This greatly increases the albedo or reflectance of solar radiation back into space, adding to the cooling effect. Oceans generally have sufficient heat capacity not to freeze over, except right near the poles.

From about 30 million years ago, the Australian continent has gradually dried out. Back then, Lake Eyre was a series of freshwater swamps surrounded by rainforest. Lake Eyre these days is a salt pan surrounded by desert. Rare freshwater inflows stimulate a bloom of brine-shrimp, which supports fish and birds for a time. Otherwise, it is about as hostile and environment as can be imagined.

The pollen record shows a gradual replacement of Antarctic Beech with Eucalypts and grasses. Climate change on this scale relates more to continental drift rather than the Milankovic cycles, to which more recent ice age and interglacial cycles can be attributed. (See figure from P.156, D Johnson)

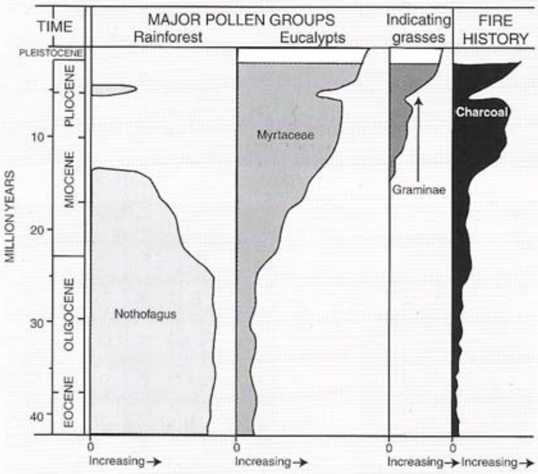


Figure 7.7 Pollen profiles from Tertiary deposits in southern Australia. Many of the genera can be matched with those in modern cool temperate rainforests of Tasmania shown in Figure 7.6. Note the change from rainforest to eucalypt and grass vegetation, with more charcoal, after 15 Ma ago, as the climate became drier.

Source: Helene Martin

About 18000 years ago, an ice age caused further drying of Australia. This was reversed from about 11,500 years ago with a warming trend which caused a sea-level rise of about 20 meters. The coastline stabilised near its present level by about 6,500 years ago. During this time, Tasmania was cut off from mainland Australia and the Gulf of Carpentaria changed from a vast freshwater lake to a saline embayment.

Anthropogenic climate change may be turning the Murray Darling Basin into a replica of the Lake Eyre Basin. David Johnson's "Geology of Australia" contains some interesting estimates of the time it took to form commercially viable coal seams. Northern Hemisphere coal was formed during the carboniferous era but southern hemisphere coal formed from peat swamps during the Permian. In cold climates, the accumulation of peat is at about 1 mm per year, or a meter of peat in 1000 years. Assuming a 1:10 compaction ratio, 1 meter of coal would take about 10,000 years to accumulate.

Tim Flannery's book "The Weather Makers" reports an estimate that each year during the 1990's, worldwide we burned coal that took 5000 years to accumulate.

Conclusions

The interaction of geology with climate overwhelming determines the site quality or productivity of any particular area. Of course, other factors such as local topography, fire history, available biota and land-use history play a part, but generally the nature of the parent material at the surface will determine what sort of plant-growth is possible for any particular climatic regime.

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