Everything you ever wanted to know about The Blue Lake - A comprehensive resource.

FACT SHEET | JULY 2014

VITAL STATISTICS

Capacity: 30,000 megalitres on current levels. One megalitre is 1000kL, one kilolitre is 1000 litres.

Depth: Maximum depth of 72m metres

Shoreline: Approximately 3.5km kilometres

Surface area: Approximately 70ha 59 hectares

Height above sea level: The crater rim is 100m 115 metres above sea level (at its highest point) and the Blue Lake water level 11.5m above sea level in 2007. The lake level is approximately 28m below Commercial St level

Water supply: Currently SA Water pumps an average of 3500 megalitres per year

Why are we called the Limestone Coast? What is an aquifer?

A huge layer of limestone sits under Mount Gambier and stretches as far away as Bordertown and down to the coast at Port MacDonnell (where it is >300m thick). It is made up entirely of fossil remains of marine animals and shells. Around thirty million years ago the relative sea level was higher and sea waters covered the entire Limestone Coast region. As the animals died they sunk to the bottom of the sea and slowly the layer of limestone was formed.

Over time, rainfall has soaked down through the surface of the ground and into the limestone which acts like a huge sponge. This layer of saturated limestone is what we call an aquifer, and essentially, the Blue Lake is a 'window' into the aquifer.

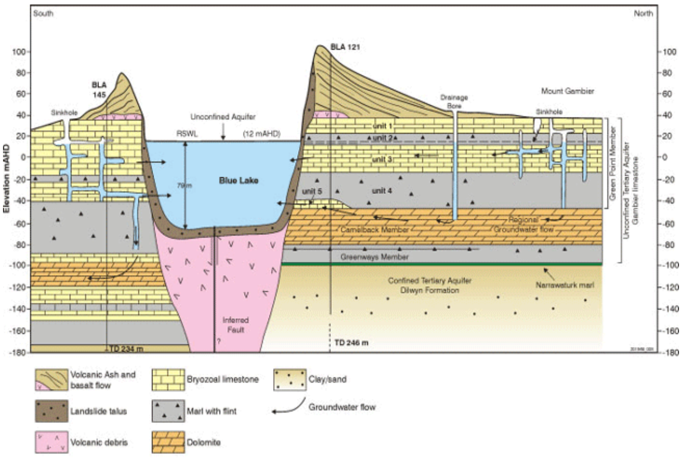
The limestone in this situation is known as an unconfined aquifer, which means the groundwater is stored at atmospheric pressure. A confined aquifer has the groundwater stored under pressure.

Limestone bricks in the amenities block at Mount Schank give little clues as to their origins.

Where does the Blue Lake water come from?

The limestone is divided into three distinct units, one of which, known as the Camelback Member, is believed to be the dominant supplier of water to the lake. Some water is also thought to leak upwards from the deeper, confined aquifer called the Dilwyn Formation. These aquifers are separated by a layer of clay known as a confining bed. The confining bed is a layer of clay which is saturated but has low permeability and cannot provide a usable yield of water. This is quite different from limestone which generally has a strong ability to supply water, allowing the groundwater to flow easily into and out of the lake.

The higher level limestone layer (commonly known as the unconfined aquifer) has the top of the water as its upper



How old is the water in the Blue Lake?

It is estimated that water from the unconfined aquifer is around 500 years old and that this older water gets mixed up with fresh stormwater collected in the city of Mount Gambier. The water in the lower, confined aquifer is much older. It is estimated that the water in the lake takes 2000 - 4000 years to travel to the coast.

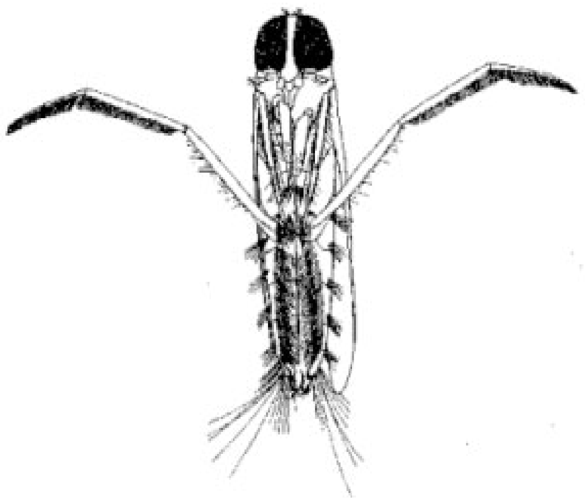
What lives in the Blue Lake?

The Blue Lake for all its colour has a low diversity of species. This may well be its natural state because despite being located within a city, the lake has faced remarkably little human impact. The colour is an indicator of the very low nutrients in the water which affects every level of the aquatic system, the fish, the aquatic plants, zooplankton (tiny microscopic animals which live in water) and phytoplankton (microscopic plants). The following list details what was recorded as living in the Blue Lake in a 1985 study:

Common jollytail or native trout. Photos courtesy of M Hammer.

- POTOMOPYRGUS NIGER (FRESHWATER SNAIL)
- CHERAX DESTRUCTOR ALBINUS (YABBIE)
- AFROCHILTONIA SP. (AMPHIPOD COMMONLY KNOWN AS SCUDS)
- CALAMOECIA GIBBOSA (COPEPOD, A SMALL INVERTEBRATE)
- AUSTROAESCHNA UNICORNIS (DRAGONFLY)
- AUSTROGOMPHUS GORDINI (DRAGONFLY)
- ANISOPS SP. (BACKSWIMMER)
- CHIRONOMIDAE (NON-BITING MIDGE)
- LEPTOCERIDAE (CADDISFLY)
- GALAXIAS MACULATUS (COMMON JOLLYTAIL OR NATIVE TROUT)
- CHELODINA LONGICOLLIS (LONG-NECKED TORTOISE)
- CHARA SP. (AQUATIC PLANT)
- BACILLARIOPHYCEAE (AQUATIC PLANTS)

Probably the most interesting organisms that live in the lake are the stromatolites. But scientists find the native trout in the lake of interest as well. They were apparently introduced into the lake, as no fish were reported prior to 1979, and their survival and evident success intrigues experts, as normally this fish migrates to sea and spawns in or near the estuary where some flow or turbulence exists. As there are no tributaries flowing into the lake they are apparently spawning in freshwater with no comparable 'flow'.



Backswimmer. Line drawing courtesy of Waterwater South East.

Important to the life inside the Blue Lake is the Chara, an aquatic rooted seaweed type plant, which looks a bit like a bottle brush and covers vast areas of the crater sides inside the lake. It is suggested that Chara is an important surface supporting much of the other life in the lake, for other organisms such as freshwater shrimp, aquatic insects (such as midge larvae) and ostracods (tiny freshwater and marine crustaceans with a shrimp-like body plus two hard shells connected by a hinge).

What are stromatolites?

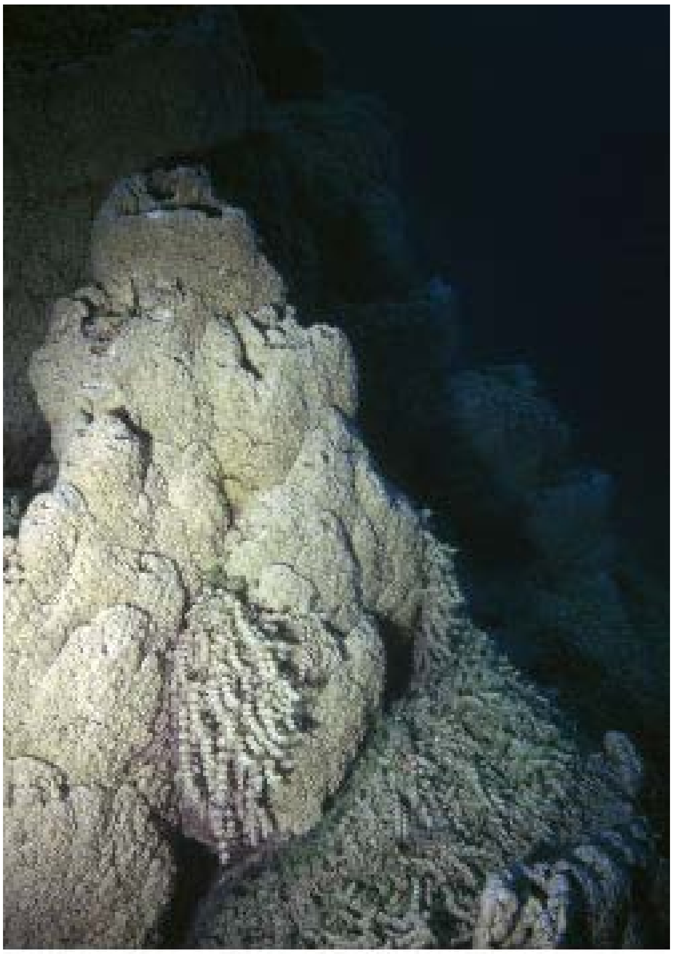
The most important living organisms in the Blue Lake are stromatolites. According to divers the stromatolites living in the lake can be over 10m tall and wide. But what are they?

Mia Thurgate, an expert who has studied these strange features and dived the Blue Lake, describes them in layperson's terms as "layered deposits of minerals, such as calcium carbonate, that have formed by the action of living organisms".

Typically, the organisms involved in constructing stromatolites are microscopic algae, although larger algae and bacteria may also play a role. These microbes tend to occur in dense communities which form a 'skin' or mat on the surface of the stromatolite. Under the surface of the Blue Lake, the stromatolites form columns of rock, covered in thin films of pink and green.

The microbes that build stromatolites change the chemistry of their surrounding environment so that minerals are precipitated out of the water. Microbes must continually push their way up through the layer of precipitated minerals to prevent being smothered. As this process repeats over time, layers of minerals are formed, so that the internal structure of the stromatolite starts to resemble the growth rings of trees. These layers are called laminations, and are the internal feature that distinguishes stromatolites from other mineral deposits formed by microbes.

Stromatolites first appeared on Earth 3.5 billion years ago. Evidence from the fossil record shows they were the dominant form of life on Earth between 2,800 to 540 million years ago, reaching their greatest diversity around 1000 million years ago. Most of the microbes which construct stromatolites are photosynthetic, that is, they use energy from sunlight, together with carbon dioxide and water, to produce carbohydrates and also give off oxygen, which is liberated into the atmosphere.



Inside the Blue Lake, 1991
Photo courtesy of M Thurgate.

Some scientists believe stromatolites were amongst the earliest living organisms on Earth that could photosynthesize. It may be that the through this activity, stromatolites fundamentally changed the Earth's atmosphere. Before they were present in large numbers, there was almost no oxygen in the atmosphere, but once stromatolites came to dominate, oxygen levels were greatly increased.

This may have provided the environmental conditions that allowed more complex life forms such as animals to evolve.

Early stromatolites were mainly found in shallow marine environments across the world. Today, they are relatively rare and mainly restricted to alkaline (such as the Blue Lake) or hypersaline waters, and also in hot spring environments. These are harsh environmental niches that few other organisms can tolerate. The reason for the decline in stromatolites and their limited present-day distribution patterns is unclear. The oceans of the world are today much less alkaline than they were in the past, so it may be that changing environmental conditions played a role.

Unfortunately for us, the stromatolites in the Blue Lake are mostly found below the water surface so they are best seen if you are diving. So what do the stromatolites under the Blue Lake look like? Mia Thurgate, who has observed at least eight different types of stromatolite diving just five locations around the Blue Lake reports:

"Many stromatolites in the Blue Lake rise out of the sediment-covered lake floor or are found attached to the sheer rock walls of the volcano. They form columns of various shapes and sizes, conical mounds, and very large reef-like structures which may be over 12m long. The largest stromatolites are found at depths of 5-10m below the surface, and typically form huge tower-like structures up to 10m tall. Isolated turrets and spires have developed on top of many towers, so that the whole structure resembles a strange rocky castle. The smallest stromatolites are usually only a few centimetres long and are mostly found in heavily shaded areas on the walls, or in very deep waters".

Stromatolites extend almost continuously from the surface of the Blue Lake to depths of 45m. At depths of greater than 10m below the surface, the shapes and forms of the stromatolites begin to change. In the deeper lake waters, the stromatolites form low mounded walls and canyon-like structures, in others areas they look like scattered rubble. Curiously, some of these deep water structures are covered in aquatic mosses and sponges that don't seem to be present in the shallower waters.

The Blue Lake stromatolites are not the only examples of stromatolites in the South East. There are also stromatolites forming in at least eight sinkhole (cenote) lakes in the region. One group of cenotes containing stromatolites is found just south of Mount Gambier, and a second group is located near Mount Schank. And there are relatives of the stromatolite, thrombolites, growing in saline lakes near Robe.

Thrombolites are microbial formations that have a clotted internal organisation as opposed to stromatolites that have a laminated structure.

Thrombolites near Robe, South East, South Australia. Photo: B Taylor, 2006.

Scientists use the term 'microbialite' as a catch-all phrase for all the different deposits formed by algae and other microbes, no matter what their internal structure looks like. Our region may well be a global 'hotspot' for microbialite diversity as over 20 different types are present in the lake environments of the South East, more than most other places on earth.

What lives in the Crater Rim?

Cats and rabbits (which are pests!) can often be seen by walkers around the lake, but a lucky observer may notice more local species including brush-tailed and ring-tailed possums, long-necked tortoise, southern water-skink, echidna, and common brown, cabbage white and grass blue butterflies. Local naturalist, Bryan Haywood, says the crater is also a likely habitat for various significant butterfly species including the bright-eyed brown and the white-banded grass-dart, and you may hear red-eye and coastal ticker cicadas. Keep your eyes peeled for reptiles such as the lowland copperhead snake, which also frequents the lake edge and rim.

Photo above - of the Northeastern side of the Blue Lake by B Haywood, 2007

Red-eyed cicada from around the Blue Lake. Photo: B. Haywood, 2006.

The easiest animals to spot around the Blue Lake are the birds. There are many superb fairy-wrens, grey fantails, red-browed finches and New Holland honeyeaters to be seen. There are also birds introduced to Australia such as black birds and the European goldfinch. Some of the more rare birds you might catch a glimpse of are the peregrine falcon, yellow-tailed black cockatoo, Australasian grebe and nankeen night-heron. Others birds that frequent the crater rim are the white-browed scrub wren, golden whistler, pacific black duck, little pied cormorant, silvereye, great cormorant, brown thornbill, dusky moorhen, welcome swallow, willie wagtail, grey shrike thrush, magpie-lark and yellow-faced honeyeater.

It is believed that the pre-European vegetation for the lake crater was grassland with sparse cover of trees and/or shrubs. Before European settlement the dominant species of trees were acacias, heath and casuarina.

Today drooping sheoak is the most common remnant tree species around the Blue Lake. This tree, as part of open woodland habitat, is endangered in the South East of South Australia.

Copperhead Snake. Photo courtesy of Forestry SA, 2006.

Over 24 native plant species were recorded in a survey of the Blue Lake crater during 2003. Two plants of conservation significance found at that time are coast bush-everlasting and boobialla. There are also many weeds growing in the crater rim, such as olives, pines, cypress and SA Water has a management plan in place to care for the crater environment. If you see tree stumps in the crater rim, this is part of a plan to remove weeds from the area.

Why is the Lake so blue?

The water in the Blue Lake is clear due to several important natural cleaning processes. Groundwater entering the lake is cleaned or 'treated' as it moves through the limestone aquifer. The aquifer removes organic matter, which can give water a yellow to brown stain much like the way tea leaves colour tea brown. The limestone aquifer also takes out phosphorus and this limits the amount of algae that is produced in the lake.

Why does the Lake change colour?

The colour change happens over a few days in late November and early December and continues to deepen during summer. There are many theories about the famous colour change of the lake, from grey in winter to vivid blue in summer – the following explanation summarises the general understanding from recent research.

To help yo uunderstand the reasons for the colour change, we include the following glossary of terms:

Soluble: capable of being dissolved in another substance, as salt is soluble in water.

Particulate: very small solid suspended in water.

Precipitation: refers to the chemical transformation of a substance in solution into an insoluble form (precipitate).

Scattering of light: is the ability of water and other matter to change the direction at which light is travelling.

Stratification: is the formation of separate layers (of temperature, plant or animal life) in a lake or reservoir. Each layer has similar characteristics, such as all water in the layer has the same temperature. Or – the division of water in lakes and ponds into layers with different temperatures and oxygen content. Oxygen content declines with depth, while the uppermost layer is warmest in summer and coolest in winter.

Tannin: in this instance refers to general organic matter.

The clear water in the Blue Lake turns vibrant blue in summer for two reasons. First, the higher position of the sun in summer means more light hits the surface of the lake. This increases the blue light that is scattered back out from the lake by small particles. Pure water tends to scatter light in the blue range, small particles (such as CaCO3 or calcium carbonate crystals) scatter light in the blue-green range and dissolved organic matter (tannins) scatter in the yellow-brown range.

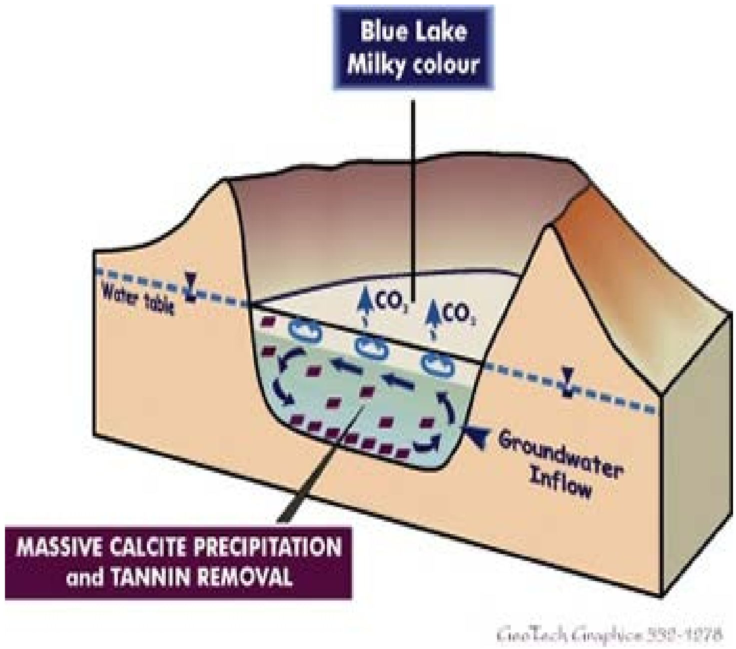
During spring the surface of the lake warms, dissolved carbon dioxide is released into the air as a gas, the pH increases and this water becomes over-saturated in calcite which begins to precipitate out. Tiny calcite crystals form and fall to the bottom of the lake capturing organic material as they fall and 'cleaning' it from the water. Each year a new layer of calcite about 3mm thick and organic material 1mm thick settles on the bottom of the lake.

It is generally accepted that there is an annual calcium precipitation cycle which has a role in clarifying the lake around November, which precedes the colour change to blue. The hardwater of the lake acts to maintain equilibrium according to the following equation:

$$CO_2 + H_2O + CaCO3 \rightleftharpoons Ca^{2} + HCO_3$$

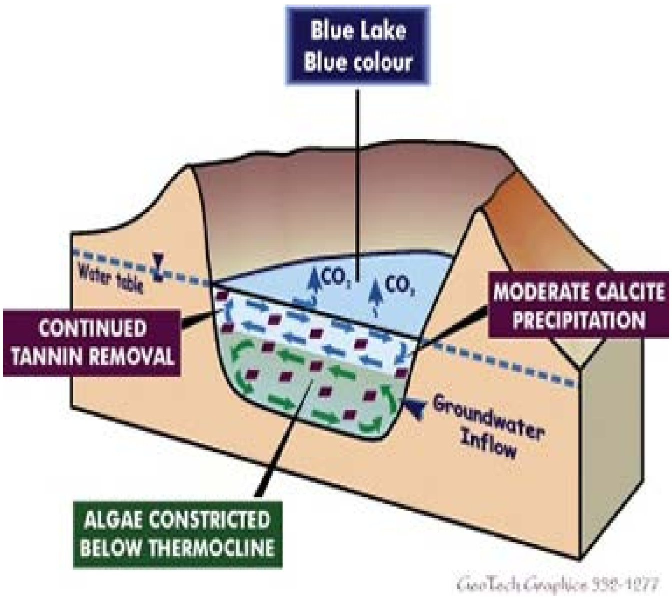
$$\text{Carbon Dioxide} + \text{Water} + \text{Calcium Carbonate} \rightleftharpoons \text{Calcium} + \text{Bicarbonate}$$

An important influence on the calcium carbonate equilibrium is the concentration of carbon dioxide (CO2) in the water. An increase in CO2 (and acidity) shifts the equilibrium reaction to the right and leads to calcium carbonate dissolving into the water; while a decrease in CO2 shifts the reaction to the left and leads to CaCO3 precipitation. In the Blue Lake, CaCO3 precipitation occurs in response to carbon dioxide gas being released into the atmosphere from the warmer surface layer.



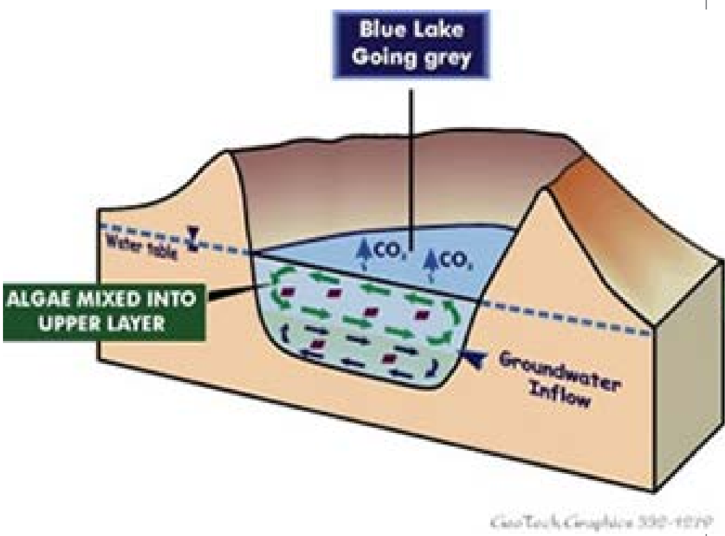
The highest calcium carbonate concentration within the Blue Lake has been reported in winter, corresponding to a period of low clarity. The lowest concentration of suspended calcium carbonate was in summer's blue period, when the lake clarity was at its highest. It has also been found that the calcium carbonate concentration peaks after the lake waters mix and it has been suggested that this is due to an influx of calcite from the bottom the lake dissolving back into the water when the water mixes

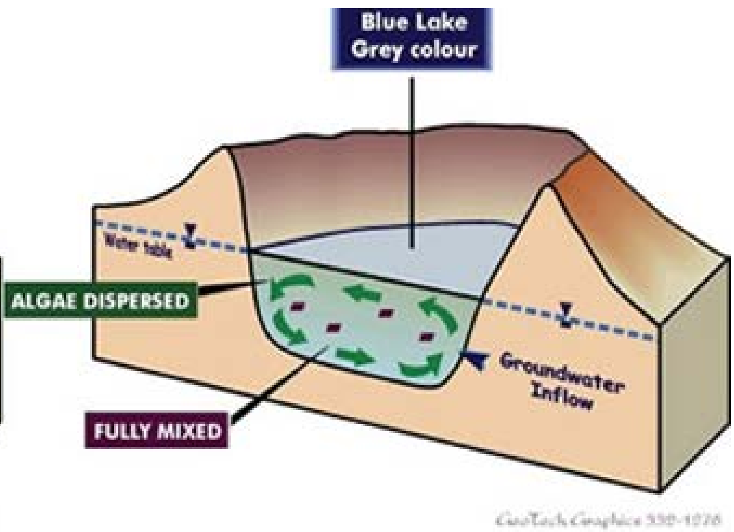
Calcium precipitation is potentially very important for water quality with the possibility for removal of both inorganics and organics, through coprecipitation. As stated above, tiny calcite crystals form and fall to the bottom of the lake capturing organic material as they fall and 'cleaning' it from the water.



By summer the lake is stratified with its warmest water in the top 15m and the coolest at the bottom, below 50m, and it is then that the lake looks its bluest.

Towards autumn, gradual cooling of the surface water triggers deeper mixing, there is no longer a defined warm layer on top, which brings water with a high dissolved carbon dioxide concentration to the surface where it is released as a gas and a second round of calcite precipitation and cleaning occurs. Further deepening and cooling of the surface layer causes calcite precipitation rates to reduce, leading to a lower clarity and the colour change from vibrant blue to grey. By winter the whole lake is well mixed and the temperature is uniform throughout. Then the cycle begins again.





What is the natural history of the Blue Lake?

Scientific studies of sediment cores from the Blue Lake suggest it was formed more than 28,000 years ago. This time corresponds to the last ice age, when the sea and groundwater levels were much lower (up to 150m lower). Before 15,000 years ago the lake was, on average, shallower than today and at times was probably less than 10m at its deepest point; because of this the original water temperature was relatively high and then gradually decreased with an increase in water depth.

The same study revealed that from 15,000 years ago the level of the Blue Lake started increasing to a level which was slightly above that which it is today. It has remained around the current level for the last 7000 years. Until pumping from the lake commenced at the start of last century, the lake was in a hydrological steady-state with a regular sedimentation rate. Since pumping began in 1884, the hydrological balance of the lake has been disturbed and groundwater inflow has increased. Current sedimentation rates are considerably higher than prior to pumping. It is likely that, as pumping rates have leveled off, the lake has reached a new hydrological steady-state. The residence time of water in the lake has shortened since pumping began due to induced groundwater flow. It is believed that the volume of water in the lake is renewed over a 7-8 year cycle.

How did a volcano form the Lake?

Anyone interested in a visual representation of this historical volcanic event should view the free film “Volcano” at the Main Corner, Mount Gambier.

Mount Gambier and the Leg of Mutton, Valley, Brownes and Blue lakes form what is called the Blue Lake complex. The entire complex and the other interestingly shaped vents and blowholes around the city were created thousands of years ago by a volcano. Recent research suggests that the volcano formed at the top of a deep-seated fault line. Although carbon dating put the volcanic event at around 5000 years ago, sediment samples from the bottom of the Blue Lake suggest it is much older – so we still have a lot to learn!

One thing we can be absolutely sure of is that molten rock (called magma while it is inside the earth and lava when it flows from a volcano) rose from deep below the Earth’s crust and came into contact with water (the saturated limestone aquifer) near the surface. This caused a series of tremendous explosions which shattered the surrounding rock and initiated volcanic eruptions. This type of eruption is explosive. A tall cloud composed of steam, gas, lava and pieces of rock torn from the vent billowed up above the crater and rained ash and rock fragments across the countryside. The result was a low cone of newly formed debris around a steep-sided vent.

Layers of ash and possibly spattered mud from a lake bottom, which have been shaped during flight after the explosive eruption of an earlier crater lake. Taken in the cutting on the western side of Crouch Street South. Photo D Sexton, 2007.

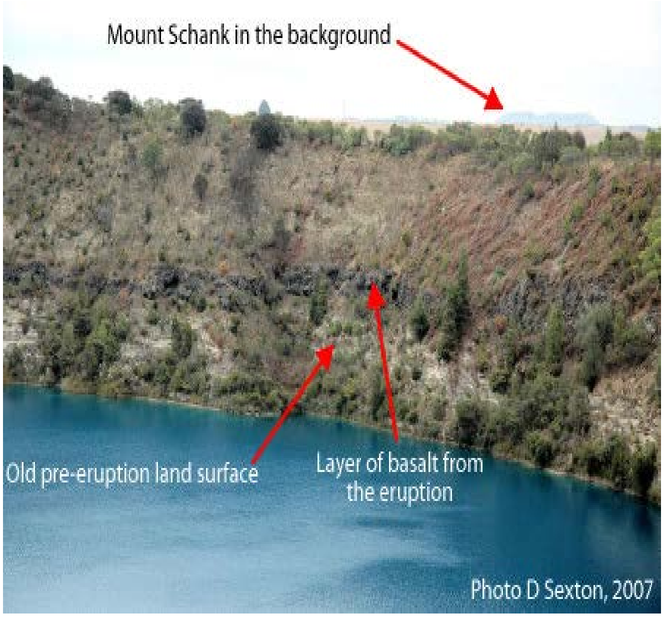
The ash that fell around the eruption is not ash as one might recognise from a wood fire, but volcanic ash. Volcanic ash, in spite of its name, is not a product of burning; it is pulverized local rock or lava (composed of crystals, glass and fragments of basalt) or a mixture of all these. Dust, the very finest volcanic ash, sometimes travels great distances in the upper atmosphere and can cause spectacular sunsets. The evidence of those clouds of ash and fragments is everywhere in Mount Gambier.

The photos below feature leaf impressions which formed when leaves were caught in falling ash. The ash must not have been so hot as to burn the leaves, but it was clearly very fine:.

These fossils are believed to be of banksia leaves and bracken fern.
Photos courtesy of Forestry SA who uncovered the pieces during excavation adjacent to Jubilee Highway East, 2006.
Photos D Sexton, 2007.

Mount Gambier is a maar volcano, a type which is produced when rising basaltic magma comes into contact with groundwater close to the Earth’s surface. As mentioned, the interaction of hot (1200 degrees Celsius) magma and cold water is explosive. The over-lying rocks are shattered by the explosive release of superheated steam.

As a typical maar volcano, Mount Gambier has a wide funnel-shaped crater. This is ringed by a very low cone which slopes gently away from the crater. The cone is built of layers of ash and large basalt lumps, known as bombs, along with local rock material such as limestone and dolomite ripped from the crater walls. In maar volcanoes the crater floor lies below the pre-eruption land surface, evidence of a collapse process. You can see the old land surface before the eruption from the limestone layers around the crater rim. At present the lake floor lies at least 100m below the old, pre-eruption land surface.



You can see the layer of limestone which indicates where the level of the land pre-eruption surface would have been, with a layer of basalt or volcanic material over the top of it. Tower Hill, a volcano near Warrnambool, is another example of a Maar maar volcano and worth a visit if you are interested in volcanoes.

This close-up of the basalt at Nurse's Landing shows bubbles where gas escaped before the lava solidified into rock. It is easy to imagine it as liquid lava, which once flowed from a fiery crack or fissure under the present Valley Lake.
Photo D Sexton, 2007.

According to Malcolm Sheard, a geologist with much local experience, the initial eruptions commenced at two sites, one around the western end of Tension Woods College oval and the other near the Leg of Mutton Lake crater. Small, low maars were quickly formed, blanketing the surrounding area in up to 2m of ash and lapilli (small pea-sized fragments which result from volcanic explosions). Lava then flowed from a fissure (western part of the complex) and a vent (Leg of Mutton crater area), but the two relatively small flows did not join together. A scoria cone developed adjacent to, and partly over, the western lava flow. He describes a section of this cone visible in the Brownes Lake western crater wall. Scoria is lava full of gas holes, frequently formed in golf-ball sized fragments as the result of interaction of magma (molten lava) with water.

According to scientists, activity at Mount Gambier may have then ceased for up to 300 years allowing the ash to erode and lava to harden. A second stage of activity was more dramatic and involved a much larger area.

Groundwater interaction with several ascending magma columns resulted in a series of new maar craters. Ash, lapilli and bombs (molten pieces of magma which are shaped during flight after being ejected from a volcano) made up of the bulk of material ejected and formed layered deposits a few kilometres away – showing the power of the blasts. Activity closed with lava fountaining in the Brownes Lake crater and minor steam emissions from blowholes both within and outside the complex.

As the crater floor in maar volcanoes is under the pre-eruption land surface, the bottom of the crater that formed the Blue Lake was now well below the water table. Thus it began to fill with water which flowed through the limestone aquifer. The top of the lake reflects the top of the current watertable.

Photo of locally collected scoria, photo D Sexton, 2007.

Is Mount Gambier's volcano extinct?

The largest and most active volcanoes are generally found where crustal plates are interacting, but Mount Gambier is not this type of volcano. It is related to a moving 'hot spot' within the earth rather than the edge of moving plates. The young basaltic volcanoes Mount Gambier, Mount Schank and those across the border in Victoria, whose short-lived eruptions began and finished quite quickly (in perhaps just days, months or years are unlikely to erupt again.

This volcanic province, with numerous eruption points scattered over a broad area (there are 400 small volcanoes between Melbourne and Mount Gambier) is best understood in terms of deep-seated fault lines which intermittently (over geological time periods) provide a conduit for magma to rise to the surface.

The province as a whole can be considered as still active, and the possibility of further new volcanoes is very real. However individual volcanoes of the past, such as Mount Gambier are extinct.

Credits

Pierce, B. E, Lloyd, L. N, Horne, P June 1985, 'The Biology of the Blue Lake', River Murray Research Group, Department of Zoology, The University of Adelaide, South Australian Naturalist vol. 59, No4 pp 63-66

Thurgate, M.E. 1996, 'The Stromatolites of the Cenote Lakes of the Lower South East of South Australia'. Helictite, 34 (1): 17-25. Thurgate, M E 1996, 'Stromatolites of the Karst Lakes of the Mount Gambier Region. What are they and why should we care?' Journal of Australasian Cave and Karst Management Association Inc. vol 23 pp. 29-33

Thurgate, M E 1998, 'The Stromatolites of the Blue Lake Crater, Mount Gambier, South Australia' in possession of the Author

Dr Phillip Playford as quoted on ABC, 2007, Stomatolite Fact Sheet, 8/12/2000, Gardening Australia ABC Web Page, viewed 25/1/07, http://www.abc.net.au/gardening/stories/s226982.htm

Government of Western Australia 2007, What are stromatolites?, Department of Industry and Resources, Geological Survey Web Page, viewed 25/1/07,

J Vanderzalm, S Lamontagne, B Sherman and P Dillon, Protecting the Blue Lake from land use impacts, Task 2: Target Condition Report, CSIRO, January 2006

Andrew Telfer & Kylie Hyde, Australian Water Environments Pty Ltd

J Vanderzalm, S Lamontagne, B Sherman and P Dillon, Protecting the Blue Lake from land use impacts, Task 2: Target Condition Report, CSIRO, January 2006.

Telfer, A.L. 2000. Identification of processes regulating the colour and colour change in an oligotrophic, hardwater, groundwater-fed lake, Blue Lake, Mount Gambier, South Australia. Lakes and Reservoirs: Research and Management, 5:161-176.

Turoczy, N 2002. Calcium chemistry of the Blue Lake, Mount Gambier, Australia, and relevance to remarkable seasonal colour changes. Archives of Hydrobiology, 156:1-9

FWJ Leaney, GB Allison, JC Dighton, S Trumbore, 1995, 'The age and hydrological history of the Blue Lake South Australia' Palaeogeography, Palaeoclimatology, Palaeoecology vol 118, pp.111-130

Mines and Energy South Australia 1995,'The geology of South Australia Volume 2', The Phanerozoic, Bulletin 54, Newstyle Printing Pty Ltd

Department of Industry, Geological Survey of Victoria, 'The Geology of Tower Hill', Birch, WD, 2000

'Volcanoes in Victoria' Royal Society of Victoria Geological Museum 1977 (UK),

'Volcanoes', Her Majesty's Stationary Office for the Institute of Geological Sciences.

Joyce, EB, 2005, 'Book Review; Australia's Volcanoes' Lava News, Newsletter for the Learned Australasian Volcanology Association

Geological Society of Australia, vol 12, pp 15-16

For more information contact Natural Resources South East on 08 87351177