Hydrogeology of the Lake Condah area, Victoria.

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Introduction

The proposal to restore Lake Condah to its original pre-European state requires some consideration of the interaction between the lake and the groundwater.

This short note attempts to summarise the geology and landforms of the Lake Condah area, western Victoria, and how this may effect the movement of water between the lake and the surrounding rocks and sediments. It is based on general principles, given the types of rock found in the area - I have done little field work on the local hydrogeology.

Lake Condah, and Condah Swamp to the north, formed as a result of the damming of the ancestral Darlot Creek by lava flows from Mount Eccles about 30,000 years ago (but that age is subject to new data from the current Lake Surprise core study). The same lava flow (the Tyrendarra flow) also blocked side valleys of the creek further downstream.

Prior to the eruption the valley was deeper and cut into both older volcanics (1-5 million years old) and limestones. The valley would also have had a fill of alluvial material. A drill hole south of the Condah Mission suggests that this included river gravels (Gill, 1979), and there has been a suggestion (e.g. by Boutakoff, 1963, p.88) that in fact the Darlot Creek valley may once have been a southern route of the Wannon River before it was diverted westwards into the Glenelg by a series of older lava flows. This is fairly speculative, but none-the-less we must remember that there could be porous sands and gravels beneath the less permeable muds and peats of the actual lake and swamp deposits.

Potential aquifers and leakage routes

The Tertiary limestone.

The geological map shows limestone and marl (impure limestone) underlying parts of the local area. Exposures of this can be seen in the pale-coloured friable cliffs of Darlot Creek at the Condah Mission. The limestone is a fairly soft calcareous sand and silt which has both a natural porosity between the grains, and also localised secondary porosity and permeability in the form of solutional tubes and cavities (including some caves, but dominantly smaller holes). This solutional porosity is referred to as 'karst'. This makes it an excellent aquifer capable of storing and transmitting groundwater readily. The solutional channels could provide quite strong and directional conductivity in local areas - but this is difficult to predict. These karst channels also present a problem for potential pollution as the flow through open conduits does not filter bacteria and can allow other pollutants to move rapidly in unexpected directions.
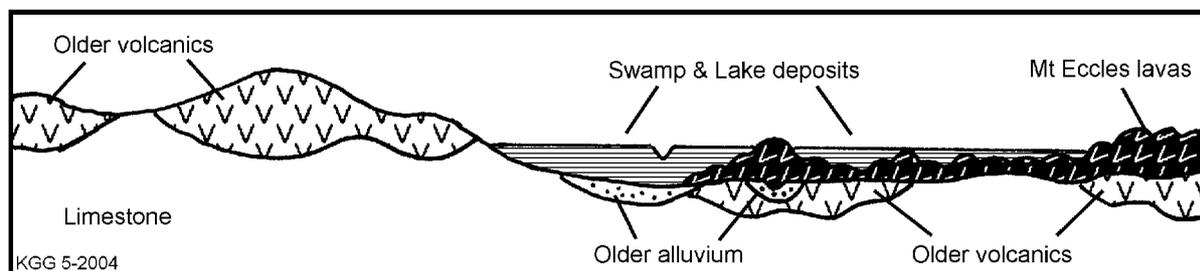

Figure 1: Diagrammatic cross-section showing the types of rock present in the area, and their possible relationships.

The limestone underlies the whole area (Figure 1), but is locally hidden beneath the older volcanics (see below). These volcanics filled an irregular topography of valleys and hills, so for any part of the swamp and lake it is difficult to be sure whether the floor overlies limestone or older volcanics. Determining this would require expensive geophysics and/or drilling and is not justifiable.

The older volcanics.

These range back to 5 million years or so in age, and are formed dominantly of basalt lavas, with minor tuff and scoria. They have been deeply weathered to form heavy clay soils - typically black and red. Beneath this impermeable soil cover the rock is partly weathered so some of its initial porosity (as described below for the Mt Eccles lava flow) may be occluded by clay material. Thus it is a potential aquifer, and has been tapped for water by bores in other parts of the region. However, its significance as a potential leakage route from the lake bed is probably limited. Because of their thick soils these volcanics do not crop out well, but have been mapped in the lake area. As discussed in the previous section their contact with the underlying limestone is an irregular surface of valleys and hills (Figure 1), so it is difficult to be sure to what extent they underlie the lake and swamp floor.

The Mt Eccles volcanics.

Current data suggests that the main eruption of Mt. Eccles occurred between 27 and 30 thousand years ago (Head, & others 1991), but the recent drill core from Lake Surprise may produce new information that requires a change in those numbers. Of main interest to this report are the fresh "stony rises" lava flows that adjoin the lake to the east and south, and which extend part way beneath the lake floor (Figure 1). Lava flows also occur beneath Condah Swamp - these may have come partly from Mt. Eccles, and partly from a continuation of the long lava flow that ran down the Harman valley from Mt. Napier.

Being young and unweathered, the initial porosity of these lavas is fully preserved and can be quite substantial - hence the complete lack of surface streams within the stony rises. Lava flows have several types of porosity and permeability that can store and transmit groundwater (Macdonald & others, 1983; Kiernan & others, 2003). These are illustrated in Figure 2. The distinction between permeability and porosity is important here, and is defined in Appendix 1. It is permeability (the ability to transmit water) that is of most relevance to this study.

Horizontal permeability: The stony rises are composed of many stacked lava flows. Individual lava flows can range from less than 0.5 metres to more than 5 metres thick, but are typically about a metre. There are two main types of lava: the more fluid *pahoehoe* has a smooth or wrinkled surface whereas *aa* is a stiffer lava that breaks up to form a jagged rubbly surface. The contacts between flows are irregular, but mainly sub-horizontal, and are marked by gaps between the solid surface of the underlying flow and the partly solidified base of the upper flow (Figure 2). These gaps can provide a strong horizontal permeability. The contacts may also be marked by permeable aa rubble zones.

Within any flow unit we frequently find porous vesicular (bubbly) bands at top and bottom of the flow, and a more solid core – for thin flows the solid core may be absent. If these bubbles are connected they can provide a horizontal zone of good permeability; if not, the permeability will be less.

Most of the young lava flows in the area would have been fed by lava tubes: conduits that carried liquid lava beneath a solidified crust. These tubes can partly drain at the end of an eruption to leave open conduits up to several metres across and hundreds of metres long - some lava tubes form complex maze cave systems (Grimes, 1995,1999). Such tubes can store and transmit very large amounts of water, and quite rapidly (Kiernan & others, 2003). Open lava tubes have been explored and mapped elsewhere in the Mt Eccles lava flows (Grimes, 1995; Figure 3) and are almost certainly present in the flows about and beneath lake Condah. However, they may not be obvious unless collapse of the roof has left an open entrance.

Vertical permeability: Cooling joints (cracks) form as the lava solidifies and contracts. These tend to be vertical, running into the flow, and viewed from above they may have polygonal patterns similar to mud cracks but wider-spaced and deeper. In addition larger open fissures can open up where the lava crust was arched or bent as it moved. These also tend to be mainly vertical or steeply inclined, but
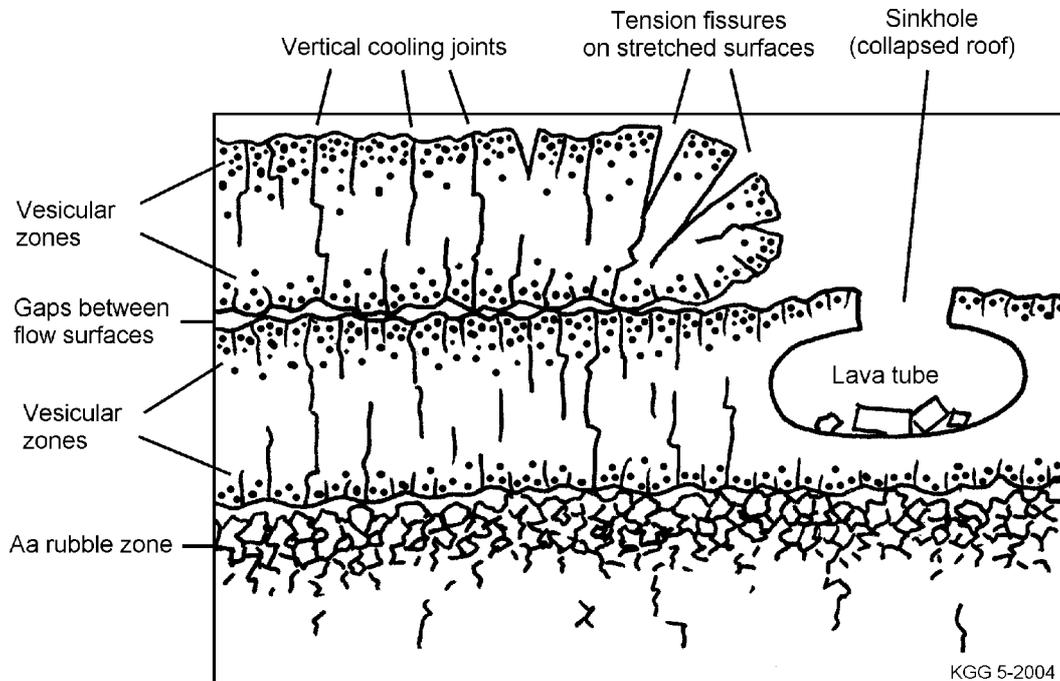
Figure 2: Diagrammatic cross-section of a set of basalt lava flows, showing the different types of permeability.

may be subhorizontal at the edges of a flow. Some fissures can be a metre or more wide and several metres deep - if the upper part is blocked with rubble they can even form small caves. Occasional collapse holes (sinkholes) can form through the thin roof of a lava tube. Note that these differ from the broader "sinkholes" formed by subsidence of parts of the lava crust while it was still soft and floating on a liquid core - most of the depressions in the "stones" are of this type rather than collapse of cave roofs.

In general the horizontal permeability exceeds the vertical permeability by one or two orders of magnitude; however the permeability in all directions is both high and locally variable. The vertical permeability allows rain water to enter the lava and then move horizontally along the bands of horizontal permeability. Local areas of high permeability can take quite strong flows of water from surface streams or the lake.

As an example of the strong permeability of the lavas of the stony rises, there is a stream sink on the east bank of Darlot Creek at the Condah Mission which takes all the base flow of the creek, although flood flows continue along the surface channel. At the time of my visit (24-4-2004) this stream was flowing at about 10 litres/second and the whole flow was disappearing into an area of basalt rubble on the bank only two metres across (Figure 4). I was told that the water reappears from springs a few hundred metres further downstream – presumably there is a lava tube or strongly permeable band connecting the two areas. During the workshop I was told of several hollows in the stony rises at the southern edge of Lake Condah which also take strong flows as the lake fills.

Thus, the stony rises at the edges of the lake and beneath it could allow a significant leakage of water from the lake when it is full or partly so. The water would mainly flow south and west through the lava field to emerge in springs along Darlot Creek further downstream. Some water could move downwards into the underlying alluvium and limestone. After strong rain, and when the lake is low (e.g. Autumn) water may move out of the lava fields into the lake area. These springs could reverse direction as the lake fills and take water from the lake.

Old alluvial deposits.

The original valley of Darlot Creek, prior to it being filled by the Tyrendarra lava flow, would have had a floor of alluvial deposits. Gill (1979) reports 12m of alluvial mud, sand and 'river' gravels beneath the lava in a borehole about 6 km south of the Condah Mission. Similar material might occur in the floor of the old valley beneath Lake Condah and Condah Swamp. If so the coarse sand and

gravel parts of it could provide a shallow linear aquifer. The narrow sinuous ridge of lava that runs out into Lake Condah from the south could have been following an old stream channel of this type.

Swamp and lake deposits.

Lake Condah and Condah Swamp are floored by several metres of mud and peat. I am not sure of the exact thickness and this could vary, being thickest in the old valley channel and thinner towards the edges. Some data could be available from the unpublished bore logs referred to by Head & others (1991) and elsewhere.

This material would tend to form a seal preventing downward flow of water into the underlying rocks and sediments: i.e. the older alluvium, the Mt. Eccles lava flows, the older volcanics and the limestone. However, where the seal is thin or absent (e.g. over lava rises) or has been disturbed by drain excavations some downward flow could occur - at rates determined by the local permeability of the underlying material.

Conclusions

The most obvious geological problem that may occur with the proposed reflooding of Lake Condah has to do with water loss into the ground. This will be mainly into the highly permeable stony rise lava flows at the edges of the lake and beneath its floor. Some losses could also occur downwards into underlying alluvium and the limestone, but this would probably not be significant.

The intention is to restore the system that was already operating, and this would, of course, have included the leakages. So some leakage should be acceptable. However, there are two differences between the original system and the proposed new one. Firstly the construction of the artificial drains may have locally broken the mud seal over the underlying permeable lava flows, alluvium or limestone. So that could produce an additional downward leakage. The most likely areas for such leaks would be where basalt blocks have been thrown up onto the banks of the drain - indicating that the channel has cut down into the underlying lavas. It would be advisable to inspect the drains in these areas and if necessary push some of the excavated mud back into the channel to reseal the floor. The drains should be reinspected several times after the lake has filled and emptied again - to look for and repair any obvious points where water has been leaking downward through "runaway holes".

The second difference is that the original system included artificial dry-stone walls, presumably coated with mud or peat, which seem intended to prevent water loss into some hollows at the lake margin (Heather Builth, pers. comm.). One suspects that those hollows connect to significant underground conduits. These walls will need repair and resealing, and ongoing maintenance. The original mud coating would have been maintained by a large on-site population that had a strong incentive to keep the system working - but that is no longer present. A suggestion made at the workshop for reducing the maintenance load was to use cement (suitably coloured) rather than mud to seal the stone walls.

One other consequence of refilling the lake on a more or less permanent basis will be an increase in water flow through the stony rise lavas. This could reactivate some springs further downstream which would have dried up after the lake was drained, and increase the flow from others. These springs would be mainly at the edge of the stony lava flow.

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Appendix 1 - Porosity and permeability.

In general usage the word "porosity" tends to be used to be used to describe both porosity (*sensu stricta*) and permeability. However, in strict usage there are important distinctions to be made when describing the water-bearing ability of a rock.

Porosity is simply the percent, by volume, of pore space within the rock or sediment. It indicates the potential to store water. *Permeability* is a measure of the rate at which water can flow through a rock or sediment. It reflects the connectivity of the pores and fractures.

A nice example of the difference between the two concepts is given by comparing an open-cell foam, which is highly permeable and can sponge up water, with a closed-cell foam which is impermeable and does not. Yet in both the porosity, the percentage of volume occupied by bubbles, is similar. The difference is that in the former the cells are joined by open connections and allow water flow, in the latter they are separate and unconnected. We see a similar difference in the vesicular (bubbly) zones of the lava flows - some are permeable and others not.
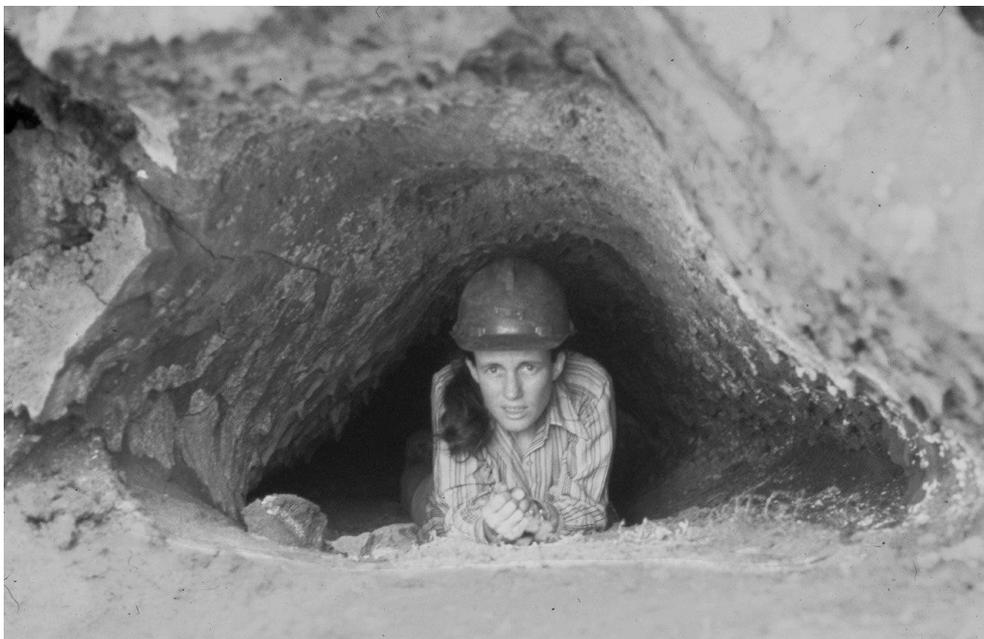
Figure 3: A small lava tube at Mt. Eccles.

Figure 4: Darlot Creek at Condah Mission. A strong flow in the foreground sinks entirely into basalt rubble (arrowed) at the far side of the pool.