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19th February, 2018.

EXPERT WITNESS STATEMENT – EMERITUS PROFESSOR RAYMOND CAS

RE- AMENDMENT C36 PLANNING SCHEME SOUTHERN GRAMPIAN SHIRE COUNCIL
PERMANENT SIGNIFICANT PLANNING OVERLAY TO HARMAN VALLEY
SCHEDULED HEARING DATES: 6TH – 7TH MARCH, 2018.
LOCATION: HAMILTON

QUALIFICATIONS AND EXPERIENCE:

• B.Sc. (Hons First Class) University of Sydney, 1970
• PhD Macquarie University 1977
• Lecturer to Professor, Monash University, 1978-2010
• Professor of Volcanology, Monash University, at the time of retirement, end 2010.
• Emeritus Professor, Monash University, 2010- ongoing, in recognition of research contributions in volcanology
• President of the International Association for Volcanology and Chemistry of the Earth's Interior (IAVCEI) 2007-2011
• Research undertaken world-wide on modern and ancient volcanoes
• 167 peer reviewed research papers (mostly on volcanology), published in international and national journals
• Lead author of then volcanology book "Volcanic Successions" (Cas & Wright, 1987) which sold over 10,000 copies internationally.
• Lead author of a new book "Volcanology" that is currently being written
• Co-author of 19 papers on various aspects of the volcanology of the Newer Volcanics Province of western Victoria and south-eastern South Australia, including the most recent and most comprehensive review paper:
• Cas, R.A.F., van Otterloo, J., Blaikie, T. and van den Hove, J. 2017. The dynamics of a very large intra-plate continental basaltic volcanic province, the Newer Volcanics Province, SE Australia, and implications for other provinces. Published in: Nemeth, K. (ed) *Monogenetic volcanism*. A Special Publication of the Geological Society of London, volume 446, doi.org/10.1144/SP446.8
• (Co-)Supervisor of 5 PhD, 6 Masters and 19 Honours research students working on Newer Volcanics Province projects
• Leader of multiple field trips for national and international research conferences and research scientists to view the volcanology of the Newer Volcanics Province, including the Harman Valley lava flow.

AREA OF EXPERTISE

• Physical volcanology

OPINION AS AN EXPERT

National and international importance of the Newer Volcanics Province of western Victoria (including the Western Districts/Plains) and south-eastern South Australia

The Newer Volcanic Province (NVP) of Western Victoria and south-eastern South Australia covers an area of over 25,000 square kilometres (Figure 1), and is classified scientifically as a still active, intra-plate, continental basaltic volcanic province. Such provinces form away from the margins of tectonic plates, which is where most large volcanoes such as those that form the Pacific "Ring of Fire" form and are active. The NVP is one of the largest intraplate volcanic provinces on Earth and because volcanic activity was distributed over such a large area, it of considerable scientific interest because of this. What caused it to form and why are volcanoes in the NVP so widely distributed.

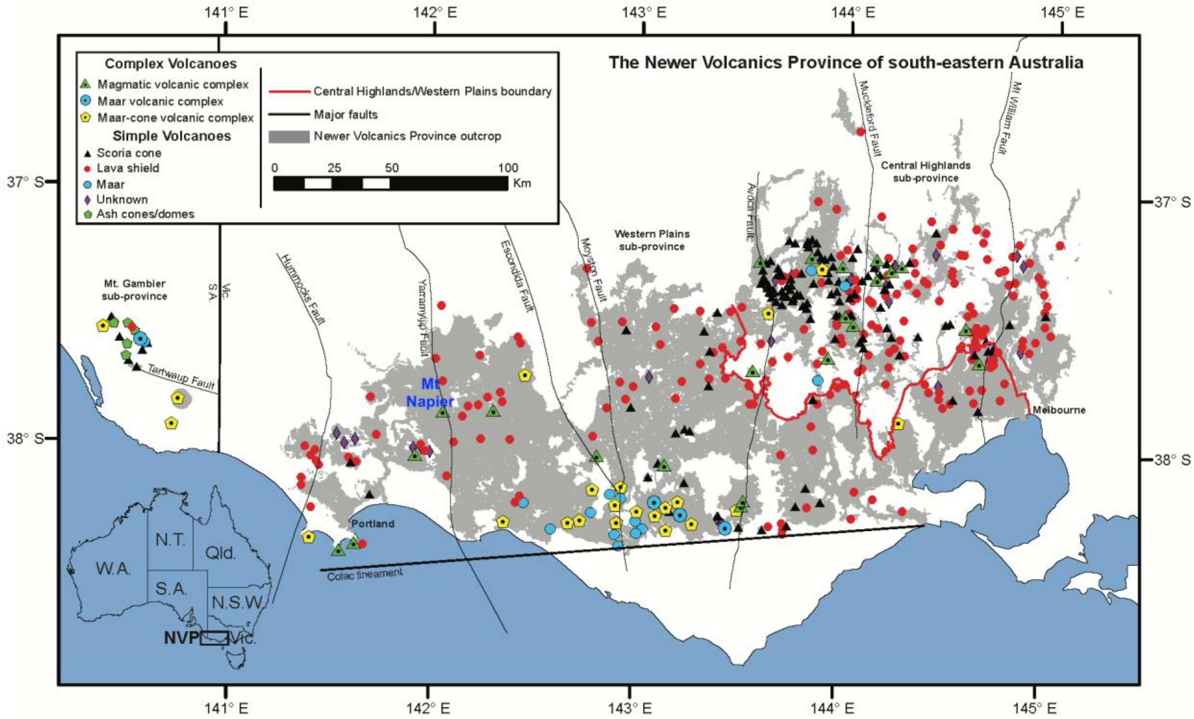

Figure 1. Map showing the extent of the Newer Volcanics Province. The grey shows the area occupied by lava flows, the symbols different types of volcanoes. The location of Mount Napier is shown by a green triangle. From (Boyce 2013)

The NVP is arguably Australia's only, still active, volcanic province. The province became active about 8 million years ago (Cayley et al. 1995; Edwards et al. 2004; Aziz-Ur-Rahman & McDougall 1966), the last eruption occurred about 5,000 years ago at Mt Gambier in South Australia (Smith & Prescott 1987).

With over 400 known volcanoes scattered across the province (Figure 1; Joyce 1975, Boyce 2013, Cas et al. 2017), this implies that volcanic eruptions occurred about every 15,000 to 20,000 years. Since the last eruption occurred only 5,000 years ago, this indicates that the volcanic province is likely to erupt again in the future. As the only still active volcanic province in Australia, the Newer Volcanic Province is therefore of major scientific significance nationally, but also to Victoria.

The majority of the volcanic province is covered by the remains of basalt lava flows (Figure 1) that have buried pre-existing topography and created the relatively flat terrain of the Western Districts of Victoria. Scattered across these lava plains are over 400 visible volcanoes (Figure 1; Joyce 1975, Boyce 2013, Cas et al. 2017), identifiable as volcanoes by the relatively prominent topographic form (Figure 2a) and the volcanic craters.

Outstanding examples of these volcanoes include Mount Elephant at Derrinallum, Mount Noorat at Noorat, the volcanic cones around Camperdown, the spectacular crater dominated Tower Hill volcano near Warrnambool, and the largest volcano in province, Mount Napier (Figure 2), near Hamilton. In South Australia, the best examples are the spectacular cones and craters at Mount Gambier, and Mount Schank.

A great deal of research has been undertaken on various scientific aspects of the volcanic province, including the volcanic eruption processes, the chemistry of the lavas, the geomorphology of the province, age dating of volcanoes and lava flows, geophysical properties of the volcanic province and its rocks, and hazard assessment regarding future possible eruptions. Much of this research has been published in international, scientific research journals (see reference list at the end of Cas et al. 2017), indicating that the volcanic province at large, not only has national, but also major international scientific significance.

The scientific and educational significance of Mount Napier volcano and the Harman Valley lava flow

Mount Napier volcano is the largest volcano in terms of volume of lava erupted, and the highest volcano (440 m asl) in the Newer Volcanics Province. It is about 45,000 years old (Oostingh et al. 2017). It is a lava shield volcano, built up mostly by the eruption of multiple lava flows giving it a low angle profile in the lower half, superimposed by a steep sided summit cluster of cones and a drained lava lake at the top (Figure 2a) that would have formed during “lava fire fountaining” style of eruption, as is commonly seen in Hawai’i (Figure 2b). Evidence of this is preserved in the form of “spatter” deposits around the summit crater rim.

In addition to the lavas that built the shield and are well exposed in the Boral quarry at the foot of Mount Napier, lava flows also spread north-eastwards towards Buckley’s Swamp, and west- south-westwards, into the Harman Valley (Figure 2c).

Because of its very well-preserved form and features, Mt Napier was the first volcano illustrated in Figure 11, of the review paper by Cas et al. (2017).

The Harman Valley lava is one of the best-preserved lava flows in the Newer Volcanics Province. Many of its original features are amazingly well preserved given 45,000 years of weathering since it was erupted. These features are similar to those developed on very young basalt lava flows erupted (and witnessed) on the volcanic island of Hawai’i in the last 50 years. By making these comparisons, as scientists, we have learned much about the eruption and the way that the Harman Valley lava flow flowed 45,000 years ago. It is thus a scientific reference example of a basalt lava flow that Australian researchers, university students and the general public can visit and learn from.

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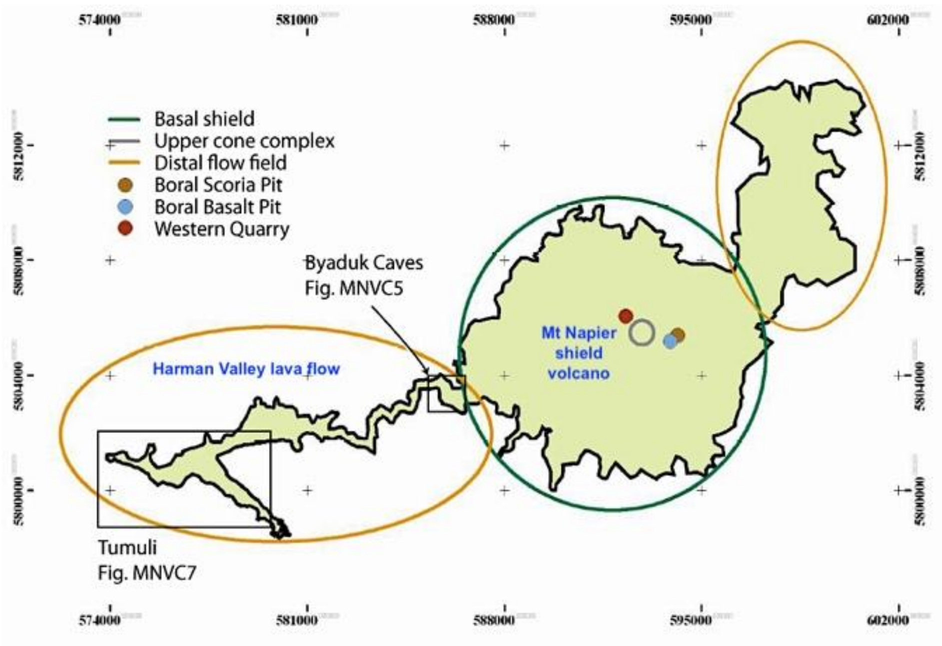
Figure 2. (a) Mount Napier shield volcano (low slopes at base) with a superimposed spatter cone complex forming the summit, viewed from Mount Rouse. (b) Fire fountain eruption at Pu'u O'o volcano, Hawai'i in 1984 feeding lava flows, and showing what the eruption of Mount Napier would have looked like 45,000 years ago. Source: Unites States Geological Survey. (c) Simple sketch map showing the extent of the central shield volcano edifice (circled in green) and the distal lava flows fields (circled in orange). From Lockhart (2007).



The major features preserved in the Harman Valley lava flow are (Ollier 1969, 1985; Joyce 1988; Cas 1989, Cas et al. 2011, 2017; see Figure 12, Cas et al. 2017):

• Pahoehoe lava surface ropy texture

There are two types of basalt lava flows, one called pahoehoe and the other a'a. These names represent the common lava flow types on the island of Hawai'i, whose eruption and formation have been witnessed. Pahoehoe lavas move slowly and are fluidal. They advance by the break out of small lobes of lava from the front of the flow (Figure 1b). As this happens a thin skin forms on the surface of each lobe and as the lobe slows down the skin crinkles to form small ropey textured ridges (Figure 1b). These features are very well preserved at numerous localities on the preserved top of the Harman Valley lava flow (Figure 3a; e.g. Byaduk lava caves, Wallacedale tumuli and other places).

• Lava tube caves and their features

As a pahoehoe lava flows away from each vent, its surface also cools and solidifies forming a crust that insulates the still liquid interior of the lava flow from cooling. A lava tube with a roof forms, and so the lava can be transferred from the vent to the advancing flow front without heat loss. During this process, the lava flow can inflate many metres. When the eruption stops lava in the tube drains and continues to flow down slope. The level of lava in the tube drops forming a lava tube cave. Sometimes parts of the roof collapse forming skylights, that allow us to not only looking to but also climb into the cave to document its internal features which allow us to develop a better understanding of the dynamics of lava flow in lava tubes (Figure 4). The best examples of these lava tube caves in the Harman Valley lava flow are obviously at the Byaduk lava caves (Figure 4a), and at some of the collapsed tumuli roofs at Wallacedale.


Figure 3 (a) Pahoehoe ropy lava texture Harman Valley lava flow, tumuli locality Wallacedale. (b) Pahoehoe ropy texture forming at the front of a lava, Hawai'I, 1989.

In the Byaduk lava caves there are internal benches and horizontal notches, as well as lava driblet lobes down the walls of the caves, and lava stalactites that represent the progressive lowering of the lava level in the lava tube as the eruption waned.


Figure 4 (a) Skylight in collapsed lava tube, Harman Valley lava flow, Byaduk. (b) Skylight into collapsed lava tube, Mauna Ulu volcano, Hawai'I, 1970. Source: United States Geological Survey.

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• *Marginal lava levees*

Not only does the surface of the lava cool but so do the sides. As these solidify they form natural lava levees that constrain lava from spreading sideways infinitely. There are many places along the Harman Valley lava flow where the sides of the lava have a relief of several metres and are very well-defined (Figure 5). These represent the original levees to the lava flow.

Figure 5 (a) Natural lava levees, Harman Valley lava flow, Wallacedale. (b) Natural lava levees forming on an erupting lava, Heimay, Iceland, 1973.

• *Pressure ridges and stony rises*

The surface crust that forms on pahoehoe lava flows can become contorted due to the pressure and shear imposed by the flowing lava in the tube on the surface crust. The surface crust can then form pressure ridges and stony rises that have a relief of several metres. Conversely, some of these irregularities may form during the waning flow stages as lava drains from the lava tube and the surface crust begins to subside irregularly. Such pressure ridges and stony rises are visible from the lookout overview on the Hamilton-Port Fairy Highway (Figure 6).

Figure 6. Hummocky stony rises surface (foreground) of the Harman Valley lava flow, lookout overview, Hamilton-Port Fairy Highway. Mount Napier is barely visible on the horizon.

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• Lava tumuli

A specific type of crust upheaval occurs when a solid crust has formed all around the top and all margins of the lava flow. The pressure inside long a tube becomes great enough to cause the weaker still plastic parts of the surface crust to dome or inflate upwards forming what are called lava tumuli. This could also occur when hot lava flows over swampy ground, causing the groundwater to volatilise and stream up through the lava building up pressure. The best examples of these features in the NVP anywhere are those in the tumuli field at Wallacedale, visible from Old Crusher Road where they are signposted (Figure 7).

Figure 7 (a) Tumulus, Harman Valley lava flow, Wallacedale. (b) Small tumuli, 1970 Mauna Ulu lava flow, Hawai'i.

• Vesicle concentration zones in the surface crust

As lava erupts, volcanic gases, which were dissolved in the lava during eruption exsolve and form gas bubbles or vesicles. If the lava is fluidal enough these gas bubbles can rise buoyantly upwards through the flow. However, if a more rigid surface crust is forming these bubbles become trapped in the crust forming a very bubble rich layer at the top of the lava flow. Such a bubble rich crust is well preserved at the tops of the tumuli at Wallacedale (Figure 8).

Figure 8. Gas bubble (vesicle) rich top of the Harman Valley lava flow, Wallacedale. (b) Vesicle rich top of lava, Iceland.

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• ***Columnar jointing***
When a lava flow ceases to flow, it slowly cools over years to tens of years. As the lava cools it tries to contract. Because it can't contract as a whole, polygonal cooling cracks and columns form on the surface and progressively propagate inwards into the centre of lava. We call this feature columnar jointing, and it is well preserved in the Harman Valley lava flow at Byaduk Caves, the tumuli at Wallacedale and along the margins of the lava flow near its end at Wallacedale (Figure 9).

• ***Summary***
The Harman Valley lava flow is unique in the Newer Volcanic Province in preserving so many features in the one lava flow. It is therefore of significant scientific and educational importance, as discussed next.

Figure 9. Columnar jointing, Harman Valley lava flow, Wallacedale.

How the Harman Valley lava flow features have been used scientifically and educationally

Many national and international scientific conferences held in Australia have had associated research fieldtrips to the NVP for conference delegates. Geoscientists from all over the world and Australia have paid significant fieldtrip fees to participate in these research level fieldtrips. Several stops in the Harman Valley lava flow are always included in these fieldtrips as a vehicle to discuss and illustrate lava flow processes and features, including Byaduck lava caves, the lava flow overview lookout on the Hamilton-Port Fair Highway, the lava tumli, lava levees and lava flow lobes at Wallacedale (e.g. Cas et al. 1984, 1993, 2011).

Secondly, the three largest universities in Victoria (Monash, Melbourne, LaTrobe) at least run annual fieldtrips for undergraduate geoscience students to the NVP, including the above stops to the Harman Valley lava flow, because of their importance as a teaching tool, to illustrate volcanic processes and features. Thousands (yes, thousands) of university students over at least the last 5 decades, as well as many lay people, as geotourists, have benefitted educationally from this opportunity.

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COMMENTS ON THE OVERLAY PROPOSAL

1. Excessive area of the overlay

Although the proposed area of the overlay includes the entire area of the lava flow in the Southern Grampians Shire, it also seems to include a large area outside of the lava flow that will unnecessarily inconvenience farmers who own properties that include the lava flow. Is it possible to redefine the area of the overlay to only include the area of the lava flow, to minimise the restrictions on the farming community?

2. Inadequate wording to prevent physical destruction of scientifically important features of the Harman Valley lava flow.

The wording of the overlay amendment does not specifically prohibit the physical destruction (e.g. through quarrying, bulldozing, forestation) of the important physical scientific features of the lava flow, as listed in this statement, and especially in the specific locations named as locations where important features of the lava flow are preserved.

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DECLARATIONS

• I have no vested interests in the area under consideration. I do not own land nor do I know anyone who owns land who may be affected. I also do not know anyone personally who has approached me to be an expert witness.

• I have not been paid by anyone or any organisation to be an expert witness.

• My interests in making this statement are entirely scientific to help protect features of the landscape that are of state, national and international scientific and natural heritage significance.

• I have made all the inquiries that I believe are desirable and appropriate and no matters of significance which I regard as relevant have to my knowledge been withheld from the Panel.

Yours sincerely,

Emeritus Professor Raymond Cas.

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