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QLD-D5 ***11 August 2012***

The Scenic Rim of Queensland: Volcanism, Xenoliths, Megacrysts, and Geomorphology of the Early Miocene Main Range Volcanics, Toowoomba

Dr Edwin Willey

QLD-D5 The Scenic Rim of Queensland: Volcanism, Xenoliths, Megacrysts and Geomorphology of the Early Miocene Main Range Volcanics of Toowoomba

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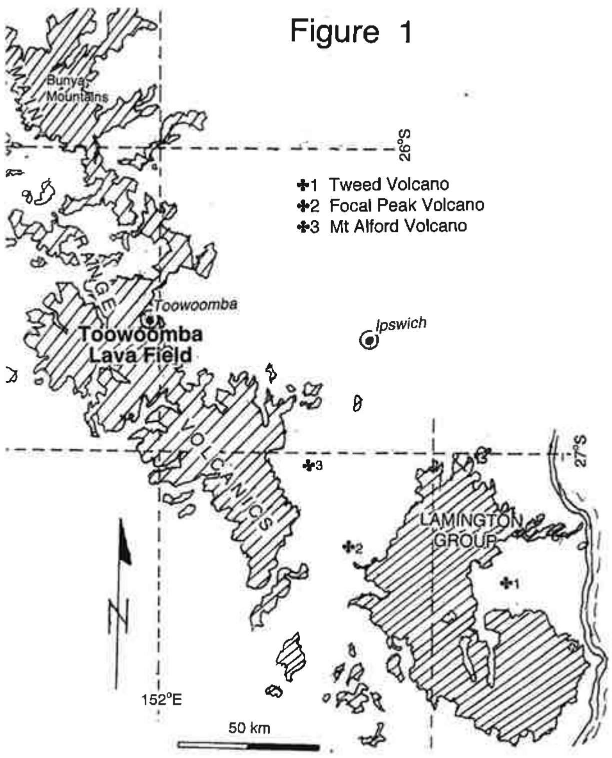
Introduction (Figure 1)

The dominantly basic Miocene volcanics of southeast Queensland are grouped in the Lamington Group and the Main Range Volcanics (MRV) along the Great Divide from the New South Wales border to the Bunya Mountains (Whitaker & Green 1980). They cover 60,000 km^2 and display a variety of volcanic expressions (Figure 1).

They includes the dissected plugs and planezes of three central type volcanoes - the Tweed Volcano (centred on Mount Warning; 20.0-22.4 Ma, Webb *et al.*; 20.5-23.6 Ma, Ewart 1982), the Focal Peak Volcano (centred on Mount Barney; 20.0-23.9 Ma, Webb *et al.*; 24.8-25.6 Ma, Ewart 1982)(Ashley *et al.* 1995) and a third centred on Mount Alford Ring-Complex (23.9-24.6 Ma Webb *et al.*) (Stevens 1962, Kean 1993). Geophysical expression of the central plugs of these three is distinctive and compare with that described at Ebor, NSW (Ashley *et al.* 1995).



The Tweed Volcano planeze is limited to the Lamington Group. The Focal Peak planeze is shared by the Lamington Group and the southern third of the Main Range Volcanics which also includes the Mt Alford planeze.

The northern two thirds of the MRV outcrop can be broadly divided in two main styles: the thick flows of the Bunya Mountains in the north (23.2-23.7 Ma, Ewart 1982) and the multi-vented thinner flows of the Toowoomba Lava Field (TLF) in the centre (see dates below). Such a summary never does justice to the variations of localised eruptive type and style, such as the Cooby Creek Trachyte (23.2 Ma, Webb *et al.* 1967) 20km north of Toowoomba, and the peraluminous leucocratic perlites, rhyolites and granophyres with normative corundum (Jeff Parkes 1989, pers. comm.) in an area of $50km^2$ around Cooyar 50 km north of Toowoomba.

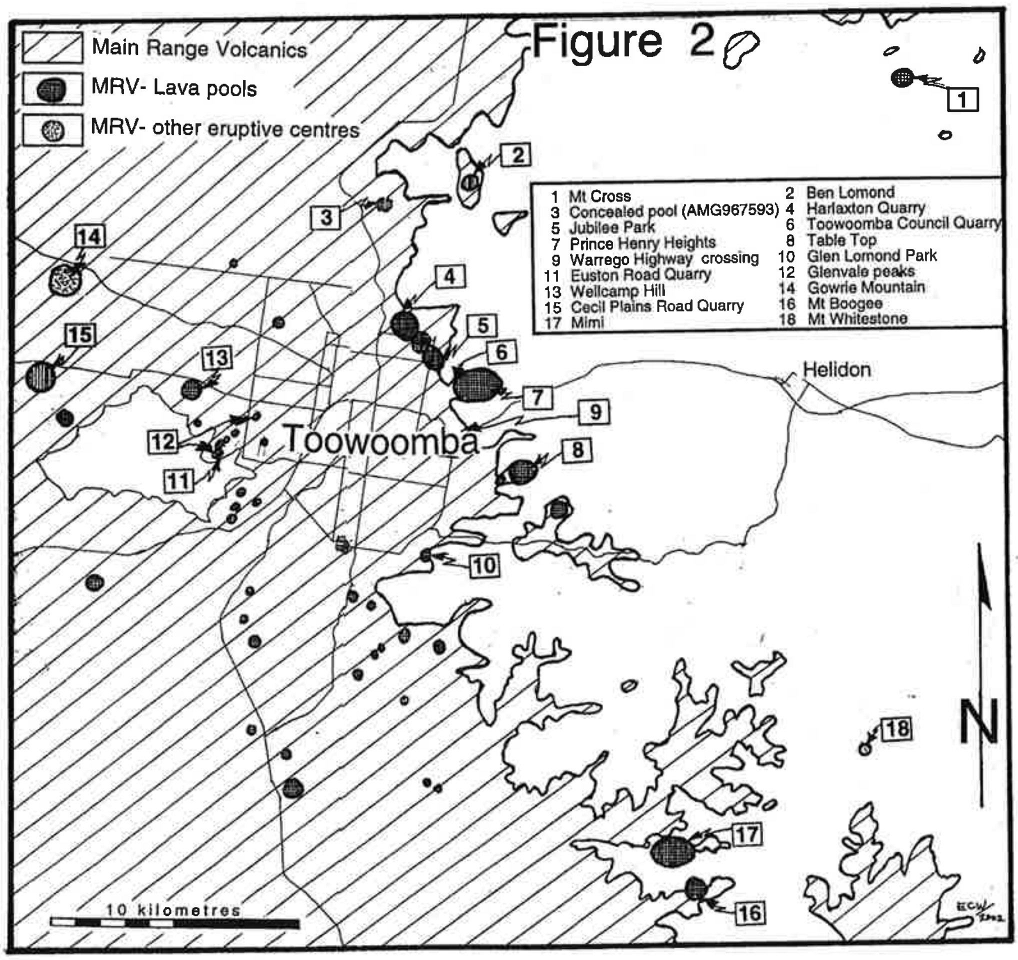
Regardless of the detailed character of these associations, these onshore volcanic associations as well as offshore seamounts are attributed to hotlines marking the passage of the plate carrying southeastern Australia over mantle hot spots (Wellman & McDougall 1974, Duncan & McDougall 1989).

Toowoomba Lava Field (TLF) (Figure 2)

Context and character

The Toowoomba Volcanics (TV) (Stevens 1969) of the MRV rests almost entirely on generally flat-lying latest Triassic to Mid Jurassic fluvial and overbank sedimentary rocks; these in turn sit unconformably on Palaeozoic sedimentary and volcanic rocks cut by Permian and Triassic intrusives, chiefly granites.

The TV erupted subaerially and is bounded by two palaeosols. It rests on the thin immature Lower Palaeosol (LP) developed on older rocks; its top is marked by the thick lateritic Upper Palaeosol (UP). Along the Toowoomba escarpment, the TV is 330m thick. A third land surface - Middle Palaeosol (MP), also lateritic - divides the TV into lower and upper units (Willey 2003).



The TV is absent 20km north of Toowoomba, and LP, MP and UP merge into a thick laterite formed on Mesozoic strata. LP and MP merge to a laterite on Mesozoic strata to the south as well as just west of Toowoomba. The MP represents a major break in volcanicity; thin boles on flow tops represent shorter periods between eruptions.

The MP separates basalts with 27.4 - 22.2Ma dates - the lower TV - from basalts dated at 21.4 - 18.2Ma - the upper TV (KAr dates, Webb *et al.* 1967, Lafferty & Golding 1985). Recent ArAr dates (Cohen 2007) yielded new insights; resampling of the locality of the oldest date above (base of the TV, Warrego Highway range crossing) has yielded an ArAr age of 40.9 Ma. Harlaxton Quarry yielded an ArAr date of 22.6 Ma, compared with the KAr date of 20.5 Ma. Gowrie Mountain and Bridge Street Quarry have KAr dates of 18.1 - 18.2Ma and 19.4Ma respectively. These three are in the upper TV. The 22-25Ma dates are contemporaneous with the Mt Alford and Focal Peak central volcanoes and the Bunya Mountains. Younger dates are from upper TV rocks of the Toowoomba Lava Field (TLF).

The TLF is developed in the interval between MP and UP. In contrast to the large volumes of the central volcanoes, the TLF is characterized by many eruptive centres, each with small eruptive volume. Those documented so far conform to the lava-pool model (Willey 2003), and range in size from 2km to only 100m across. (Figure 2)

The Lava-Pool Model (Figure 3)
The model involves two principal phases in response to rising masses of magma: a crater-forming eruption followed by a crater-filling effusion of lava, which may overflow the crest of the crater. The result is an inverted conical mass of basalt filling the crater, with possible associated flows. As the crater mass cools, joints form vertical columns at the top of the mass; these columns curve downwards and outwards, merging with columns perpendicular to the underlying sloping crater walls. Subsequent erosion of the unconsolidated crater-forming tuff undercuts the crater-filling basalt; and basalt blocks slide out along the outward dipping joints and form screes, which in time cover, conceal and protect the underlying tuff (Willey 2003.

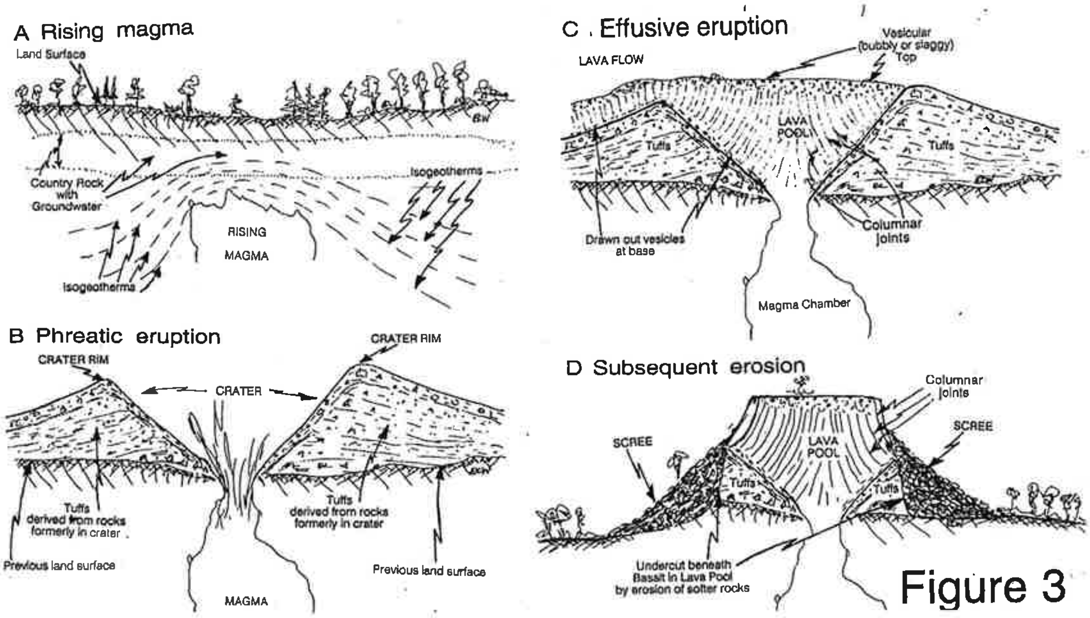


Figure 3

This model provides features allowing the identification of these eruptive centres. In contrast to the usually thin associated flows, which weather more readily, the larger and thicker lava pool masses remain much fresher, and thus provide ideal quarry sites. Typically, degradation results in lava pools forming prominent peaks of fresh basalt surrounded by screes; however, critical to identification is field observation of the basal quaquaversal columns or centrally-dipping tuffs or the basal contact itself. Other features help: thus thick (30-60m) fresh basalt masses encountered in bores are attributed to the model.

The crater-forming phase. Often the crater-forming phase is a phreatic eruption generating an accidental tuff crater, *i.e.* a tuff ring/cone (soon to be filled). This is the most common style as seen at the Harlaxton Quarry, the disused Bridge Street Quarry and elsewhere. Here, the tuffs lining the interior of the crater are usually poorly bedded and generally poorly sorted; they rest unconformably on an inclined surface often cut in underlying flatter-lying tuffs, so the phreatic eruption punctures through earlier tuffs. Outside the crater the tuffs are better bedded and sorted and at times display surge antidunes. Tuffs are ash- to lapilli-sized composed of basaltic fragments, of recycled tuffs, and of pebbles, sand and silt (derived from the Mesozoic strata by phreatic disaggregation), with some, at times ballistic, accidental blocks of basalt.

In sharp contrast, at Euston Road Quarry and Gowrie Mountain explosive magmatic eruptions formed agglutinated-bomb craters. The Euston Road Quarry eruption commenced with exhalative-fumarolic activity producing well-bedded fine ash tuff, followed by a phreatic event commencing the main crater-forming stage. The crater comprises extremely coarse phreatic tuff dominantly composed of basalt blocks (up to 1m in diameter) set in a coarse lapilli tuff, which consists of fragments of basalt, of Mesozoic shales and sandstones, of the Middle Palaeosol and of wood (now silicified). The crater-forming stage culminated with explosive magmatic eruptions with diverse bombs mantling the earlier phreatic crater. At Gowrie Mountain, the main crater-forming process also created an agglutinated bomb crater.

The crater-filling phase. Where the effusive phase follows a phreatic crater-forming phase, the base of the crater fill has a chilled margin with sheared vesicles; cooling joints extend from the vesicular base into the non-vesicular main mass of the crater fill. Where the final crater-forming phase was explosive eruptions, there is no chilled margin and cooling joints extend irregularly into the underlying agglutinated-bomb zone. Volatiles generate a thick zone of generally equant-vesicled basalt at the top of the crater-filling lava and of any flows resulting from overflow out of the crater.

Crater-fills may be from a single effusion of magma. However, there is evidence for pulsed effusions or for effusion being drawn back to the magma chamber. At least two xenolith cumulate zones, paralleling the inclined crater floor, are seen at Harlaxton Quarry, suggesting at least two pulses of magma-feed into the crater. At Euston Road Quarry, a 10-15m slab-shaped mass with equant vesicles (*i.e.* the lava pool top) dips into the centre of the crater fill to be later enclosed by non-vesicular basalt with disturbed cooling fractures; this is interpreted as a collapse into the crater as a result of drawback, followed by renewed effusion into the crater. Relationships at Gowrie Mountain suggest drawback of crater-filling lava after an effusive pulse overtopped the crater rim. Both Euston Road and Gowrie Mountain have agglutinated-bomb craters resulting from eruption of magmas high in volatiles; such melts are the driving mechanism for the explosive magmatic activity and have the potential for subsequent drawback into a gas-evacuated magma chamber.

Role of volatiles.

Volatile vesiculation is important in the volcanic processes in the TLF. It drives crater-forming in both explosive magmatic and phreatic eruptions and is responsible for other detailed features. The ultimate mantle source for volcanic materials and energy rules out primary volatiles. The explosive magmatic crater-forming eruptions at Gowrie Mountain, Euston Road Quarry and elsewhere suggest that at least some of the masses of rising magma incorporated volatiles from the rocks they passed through on their way to the surface. Likely sources of these volatiles lie in the upper crust.

However, explosive magmatic eruption is not the norm; most lava pools filled by quiet effusive magmatic eruptions into the phreatic (tuff ring/cone-style) craters.

Energy for phreatic eruptions was provided by the vesiculation of superheated groundwater in subsurface rocks. Heat from rising magma would superheat and vesiculate pore water against the pressure of overlying rocks, and provide the drive for phreatic eruptions. Mesozoic strata are generally porous and water bearing, with some horizons having high permeability. The water-bearing potential of Palaeozoic rocks is mostly limited to joints and fractures; so their role is less significant, but they certainly have provided drive for phreatic eruptions, such as the Mount Cross lava pool, which probably erupted along serpentinites in the Mt Cross Complex. Water in Mesozoic rocks may have been incorporated into rising melts to generate the explosive magmatic eruptions. The upper horizons of the Mesozoic strata and any overlying lower TV would have confined the deeper groundwater permitting superheating to cause the phreatic eruptions. The disaggregated isolated pebbles and sand and silt grains common in the phreatic tuffs reflect – at least in part – derivation from a superheated zone in Mesozoic rocks. By contrast, rock fragments, soil aggregates and large basalt blocks as found in Euston Road Quarry tuffs reflect derivation from the confining cap, which was not in the zone of superheating (and vesiculation), and are thus truly accidental tephra.

Basalt lavas have vesicular tops formed by volatiles acquired either before eruption or chiefly added as flows pass over water bodies or moist ground. Vesiculating pockets in a lava rise rapidly through the lava as single masses, shooting from the top of the flow as bombs. These bombs may sit on the flow or be reabsorbed or agglutinated into the molten lava – and the more the volatiles, the thicker this upper vesiculated zone. This zone is highly variable, but is characterised by equant vesicles. As lava flows over the ground, its vesicular top is rolled out under the flow; vesicles are sheared (stretched and flattened) as the lava moves over it. The result is a basal vesicular chilled margin 100-400mm thick. This is typical of the base of crater-fills after a phreatic crater-forming phase.

At Harlaxton Quarry and very spectacularly at the Bridge Street Quarry, the addition of volatiles from water in the crater-forming tuffs has generated fumarolic conduits. At Harlaxton, the development is localized. However, at the Bridge Street Quarry, movement of volatiles (steam from wet crater-forming tuffs) has disrupted the crater fill basalt forming rootless fumarolic conduits (shaped like tree-roots and trunk), while the source of the volatiles -the delicately bedded, fine-grained underlying crater tuffs- remained completely undisturbed. Conduits are filled with isolated masses of altered basalt embedded in a fill rich in carbonate-apatite. These conduits and other similar masses are cooling surfaces, which modify the pattern of columnar joints.

At Harlaxton Quarry thin pegmatitic veins (grainsize up to 3mm) occur. At Mimi the crater fill (below the vesicular top) has pegmatite with feldspars 50mm across, a result of trapping of volatiles in the upper levels of the lava pool.

Xenoliths and megacrysts

The mantle sourced melts have entrained several mantle solids; some upper crust components have also been entrained. The mass exposed at Gowrie Mountain Quarry (not identified as a lava pool) has a diverse assemblage of xenoliths. Ewart & Grenfell (1985) reported analyses of seven xenoliths containing variously Ol, Opx, Cpx, Amph, Spinel, Cr-Spinel and Pyrrhotite. They also provided analyses of xenoliths from Harlaxton Quarry containing Ol, Opx, Cpx and Cr-Spinel.

There are considerable variations in the xenolith/megacryst content and distribution from lava pool to lava pool. At Harlaxton, besides the cumulate zones, xenoliths occur distributed throughout, while at Euston Road Quarry cumulate zones appear to be absent. This could reflect lava viscosity, which is supported by the general coarse-grained nature at Harlaxton and the fine-grained nature at Euston Road. Entrained mantle components are rare at Bridge Street Quarry, and have not been seen at Mount Boodgee, the largest lava pool.

Occurrences unrelated to lava pools are garnet, spinel, *inter alia* at Wyangapini (?plug) and sedimentary and granophyric buchites, lhezolite and calcite-cemented tuff in the small Mount Whitestone dyke (John Roiko 1982, pers. comm.). A flow west of the Bridge Street Quarry contains occasional plagioclase megacrysts and tuffs at Ballard railway cutting contain spinel, olivine, augite and plagioclase megacrysts.

Discussion

Some lava pools (*e.g.* the Glenvale and the Harlaxton-Table Top alignments) appear to be structurally, and thus genetically, related. It is possible that all TLF lava pools are sourced in a single mantle melt which split into smaller masses on its passage to the surface. Contamination and differentiation of these masses in their progress to the surface and variation in temperature and temperature dependant properties could account for observed differences. However, this issue can only be answered with more systematic study and detailed chemistry which as yet is not available.

The Toowoomba Lava Field, in terms of size and distribution of its eruptive centres, is comparable with the Auckland Lava Field. They differ chiefly in that maars and tuff ring/cones (unfilled potential lava pools) dominate in Auckland.

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QD5 : Toowoomba Geology Excursion - 11 August 2012

Geology *en route* from Brisbane to Toowoomba along the Warrego Highway

SE Queensland geology is interpreted within the following plate tectonic context.

During the Devonian and Carboniferous east to west subduction of an oceanic plate beneath a continental plate resulted in extensive accretionary wedge development preserved in the Beenleigh (south of Brisbane), South D'Aguilar (Brisbane and northwards) and Yarraman (west and NW of Brisbane) Blocks.

At about 300Ma, oblique subduction of a spreading ridge resulted in the developing continental crust being subject to transform movement – both transpressional and transtensional. Also subduction migrated westward. The Permian Cressbrook Creek Gp and Northbrook Beds; the mid Triassic Toogoolawah Gp, and the late Triassic Ipswich CM and their deformation are result of these processes. These conditions prevailed into the Jurassic and Cretaceous affecting the Bundamba Gp, Walloon CM and subsequent strata. These conditions appear to have continued into the Cenozoic outside this region.

From the mid Cenozoic onwards, the east Australian crust and the adjacent oceanic crust of the Tasman Sea migrated northwards over hot spots. Hotlines extend from SE Queensland to western Victoria and SE South Australia.

Overview

From Brisbane to Toowoomba the road travels mostly over Triassic-Jurassic strata resting unconformably on a basement of Devonian-Carboniferous accretionary wedge rocks, cut by Permian to mid Triassic intrusions with associated volcanic and sedimentary rocks. Pockets of Cenozoic strata occur in the Ipswich area. The Mesozoic strata were deposited in three basins.

(a) The NNW-SSE trending **Esk Trough** contains mid Triassic piedmont strata dominated by coarse fluvial conglomerates, with associated andesitic volcanics of the **Toogoolawah Group**, which are cut by positive flower structures.

(b) The **Ipswich Basin** (east of the Esk Trough) contains generally south-dipping late Triassic **Ipswich Coal Measures** (the **Kholo SG** – basal breccias, conglomerates and local volcanics, and the **Brassall SG** – productive coal measures).

(a) The **Moreton Basin** contains mostly gently dipping fluvial strata of the latest Triassic-lower Jurassic **Bundamba Group (Woogaroo** and **Marburg SGs**) and the overlying mid Jurassic **Walloon Coal Measures**.

The **Great Moreton Structure** (GMS) separates the Ipswich Basin (east) from the Esk Trough (west). The NNW-SSE trending GMS is expressed in various ways including the West Ipswich Fault. West of Ipswich, the GMS forms the eastern margin of the Esk Trough; when traced northward the GMS cuts the Esk Trough at an acute angle to become the western margin of the Esk Trough some 50km to the NNW. The Moreton Basin straddles the GMS; its strata rest with minor discordance on Ipswich Basin strata and unconformably on the Esk Trough strata.

In the late Cenozoic, tectonic and climatic conditions prevailed which resulted in a stable landsurface blanketed by a thick mature lateritic soil profile. Soil-forming was interrupted by the subaerial eruption of the **Main Range Volcanics** (MRV) to recommence once eruptions ceased. Before the eruption of the MRV, the divide between east- and west-flowing streams lay at least 20km west of the present-day Great Divide. Since then, degradation has left remnant caps of the landsurface on higher ground in Toowoomba, and formed the east-facing scarp by erosion of the MRV pile by shortened, steeper east-flowing streams.

Details

Brisbane South Bank complex and the Convention Centre rest on Neranleigh-Fernvale Beds – accretionary wedge rocks of the South D'Aguilar Block. The route climbs onto the early Late Triassic Brisbane Tuff (basal Kholo SG) - a pale purple, olive greens to pink welded ignimbrite. It is exposed in cliffs downstream from South Bank; extensively quarried, it graces many buildings throughout the city including The Manor Apartments (Queen Street) and the exterior of St John's Anglican Cathedral.

After 4km and for the next 30km, the route runs over Woogaroo SG resting on Kholo SG with pockets of Cenozoic strata and Brisbane River alluvials. Once on the Warrego Hwy Ipswich Bypass and for the next 10km the route passes over the coal-bearing Brassall SG of the Ipswich CM.

The last cutting of the Ipswich Bypass exposes the Great Moreton Structure - the boundary between the Ipswich Basin and the Esk Trough. The GMS here is expressed as a westward dipping monocline in the Woogaroo SG, which eastward rest with minor break on the Ipswich CM. To the west, the Bundamba Gp rests unconformably on (and conceals) the Esk Trough.

Over the next 5km, the route travels up the Marburg SG and for the next 4km over the basal Walloon CM. For the following 25km we return to the Marburg SG clipping the Walloon CM when passing over the Marburg Range (crevasse-splay sands) and Minden Range (overbank, with a smutty layer from a weathered coal seam on south side cutting, 5m up).

Then 48km from Toowoomba, the route crosses onto the alluvial flats of the Lockyer Valley; the Great Dividing Range escarpment rises ahead and to the southwest, with the timbered dip slope on the quartz-rich sandstones at the top of the Woogaroo SG to the northwest. The Lockyer Valley flats conforms roughly to outcrop of the labile lower Marburg SG sandstones. The alluvial flats are the basis for market gardening, depending on water from alluvial gravels and its soils - a mix of sand/silt from the Mesozoic strata and nutrient-rich fragments from the MRV basalt. As a result of the 2000-2008 drought, Lockyer Creek ceased to flow, the alluvial watertable fell, and market gardening was severely affected. The flashflood, which ravaged the Lockyer Valley (and Toowoomba) on 10/01/11, and rains since have recharged the groundwater and the creek flows again.

For 20km, the Gatton Bypass skirts north of the valley on the Woogaroo SG dip slope of the Helidon Hills. The sandstones here have been and still are quarried, and have been used in Brisbane City Hall, the Treasury Building, the Great Court (University of Queensland), the interior of St John's Cathedral and many other buildings. From Helidon and for the next 18km, the route returns to Marburg SG.

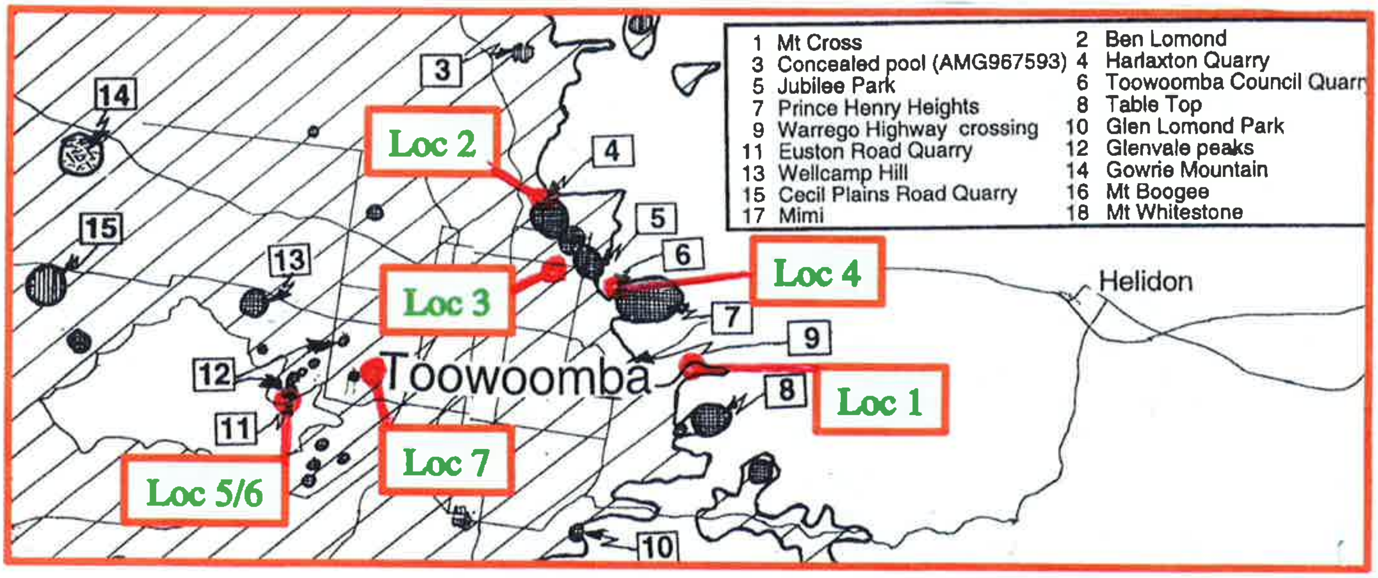
Halfway up the range crossing of the Warrego Highway (2km from Toowoomba), the MRV rests on the uppermost Marburg SG. The MRV here is an almost uninterrupted stack of 16-20 flows. The City of Toowoomba lies entirely on the eroded and degraded MRV and the latest Cenozoic landsurface laterite.

Itinerary in Toowoomba

Depart Rydges Hotel, Brisbane 7.30am

Loc 1 (stop).	Picnic Point – Introduction (Toilet) (Arrive at about 9.15am)
Loc 2 (stop).	Harlaxton Quarry (Harlaxton lava pool)
Loc 3 (drive past)	Jellicoe Street – Upper Palaesol on Main Range Volcanics
Loc 4 (stop).	Bridge Street Quarry (disused) (Prince Henry Heights lava pool)
Lunch (stop)	Webb Park (Toilet)
Loc 5 (stop).	Euston Road Quarry (Euston Road lava pool)
Loc 6 (drive past).	Euston Road – Middle Palaeosol on Walloon Coal Measures
Loc 7 (drive past).	Glenvale Peaks (lava pool) and Gowrie Mountain (in distance)
Loc 1 (stop).	Picnic Point (Toilet)

Perhaps given time, return to Brisbane via Flagstone Creek and Blanchview Roads (Mt Davison and Table Top)
Return Rydges Hotel, Brisbane at about 5.30pm



Locality 1. Panoramic views from Picnic Point. To the north, Prince Henry Heights (lava pool) in foreground and the late Cenozoic landsurface on the horizon. In the NE, Mt Cross (lava pool) and Mt Perseverance. Eastwards, the Lockyer Valley and the timbered Helidon Hills with the D'Aguilar Range on the horizon. To the SE, Table Top and Camel's Hump (foreground). Sugarloaf (Mt Davison) (behind) and Main Range spurs cut by Lockyer Creek tributaries in the distance (concealed by trees).

Locality 2. Harlaxton Quarry. The lava pool model gradually developed here as quarrying revealed new exposures. When first visited in 1973, the upper two benches had only been partly worked. The SW dip of columns was visible but not the contact with underlying tuffs nor the vertical columns now exposed in the centre of the quarry. Xenoliths are common here.

Locality 3. Sesquioxide zone of Upper Palaeosol. Once part of a larger pit extending northeastward. The sesquioxide zone provides highly stable unbound road top dressing, which retains strength so long as not water saturated.

Locality 4. Bridge Street (T'ba City Council) Quarry. The Prince Henry Heights lava pool was quarried here. Homes on Prince Henry Heights –a desirable residential area– limited eastward extension of the quarry; quarrying ceased when the quarry floor reached the tuff at the crest of the crater confining the lava pool. The lateritic Upper Palaeosol has been almost entirely removed from Prince Henry Heights, which has soils very different to those elsewhere in Toowoomba. The highwall is capped by whitish slightly-weathered basalt, which lay under the kaolinite-rich pallid zone of the UP. Throughout the quarry, rootless fumarolic conduits disrupt the base of the crater-filling basalt; the source of volatiles creating the conduits must lie in the completely undisturbed underlying crater-forming tuff, which would have been wet as basalt filled the crater. Conduits would have vented as hornitos at the top of the lava pool. The prominent sheet jointing cutting the highly-disturbed columnar jointing yields slabs of rock which have been extensively used for kerbing and guttering in older city streets – a heritage listed feature.

Lunch. Webb Park provides a fine view towards the southeast.

Locality 5. Euston Road Quarry (see guide). This lava pool displays complex crater-forming with a *cyclopean* phreatic tuff and explosive magmatism. Quarrying and drilling has revealed a slab of equant-vesicled basalt dipping into the massive basalt filling the crater. Xenoliths are varied and common here.

Locality 6. Sesquioxide zone of the Middle Palaeosol. Here the MP is developed on Walloon CM, which have been cut by a water bore in Spring Creek east of the Euston Road Quarry.

Locality 7. Views of NE-SW aligned pools of the Glenvale Peaks, and Gowrie Mountain in distance (see guide).

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