The Geology Beneath the Hobart CBD:

What Do We Know, and What do we Need to Know?

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01Dec22

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Introduction

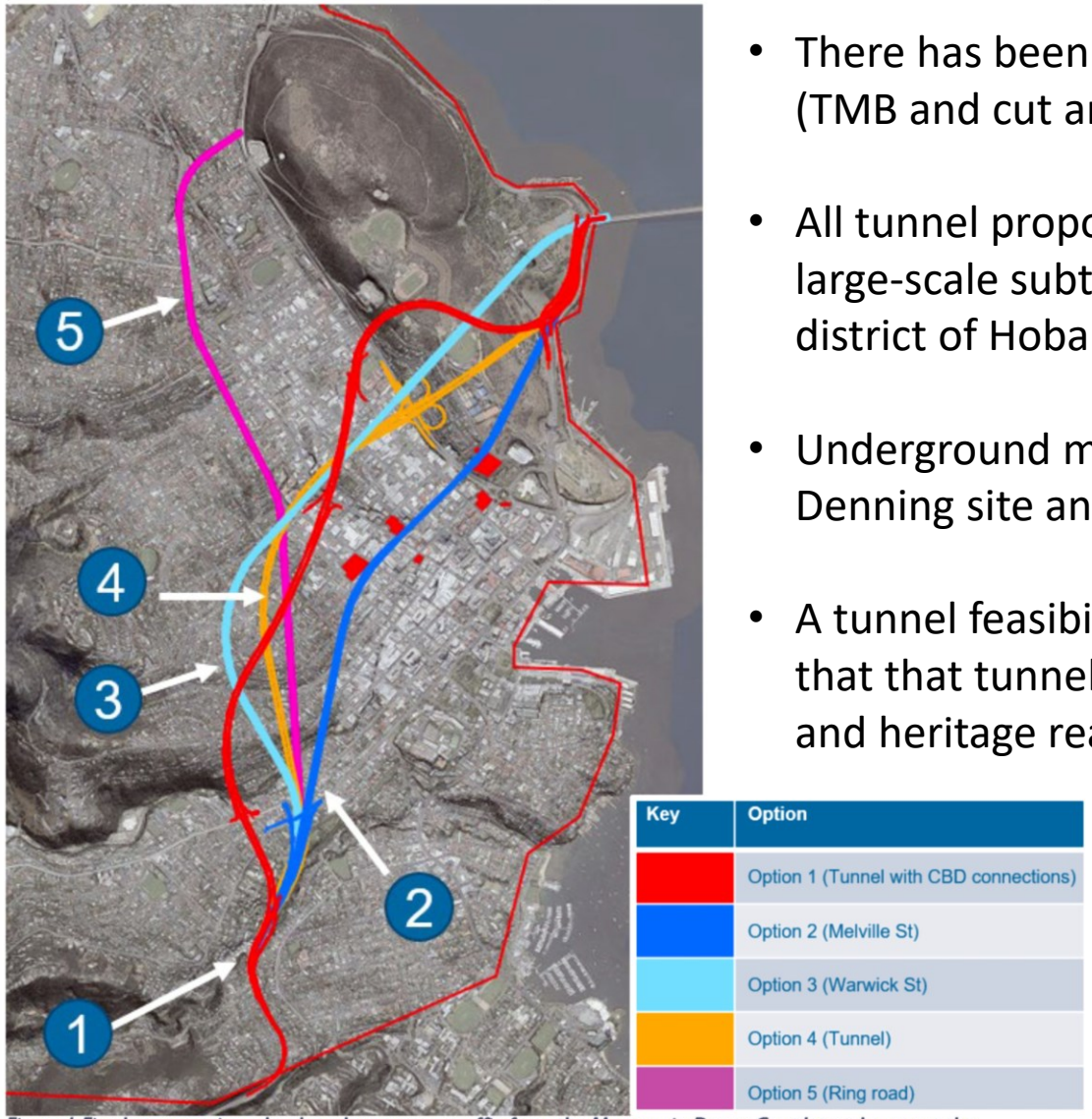

Figure 1 Five bypass options developed to remove traffic from the Macquarie-Davey Couplet and connect the Southern Outlet to the Brooker and Tasman Highways.

Hobart Western Bypass Feasibility Study – Summary Report 7

- There has been considerable recent media discussion about proposals for tunnels (TMB and cut and cover) to bypass the Hobart CBD and alleviate traffic congestion
- All tunnel proposals required the excavation of around 400m of major tunnels, and large-scale subterranean chambers in the rock mass below the central business district of Hobart.
- Underground multi-storey carparks have also been suggested (The Kemp and Denning site and as an option for any Macquarie Point Development).
- A tunnel feasibility study was undertaken on behalf of the HCC by GHD. It found that that tunnels were not a viable option for Hobart for economic, urban impact and heritage reasons.

Important Note: The DIER feasibility study (done by GHD) found that tunnels were not likely to be a viable option at present.

The specific traffic, geotechnical and heritage conditions present in Hobart made tunnels unlikely to be a viable solution in the foreseeable future.

Both shortlisted options were found to be technically feasible and would deliver approximately 2-4 minutes of travel time savings but neither option was found to be commercially attractive .

Hobart Western Bypass Feasibility Study – Summary Report

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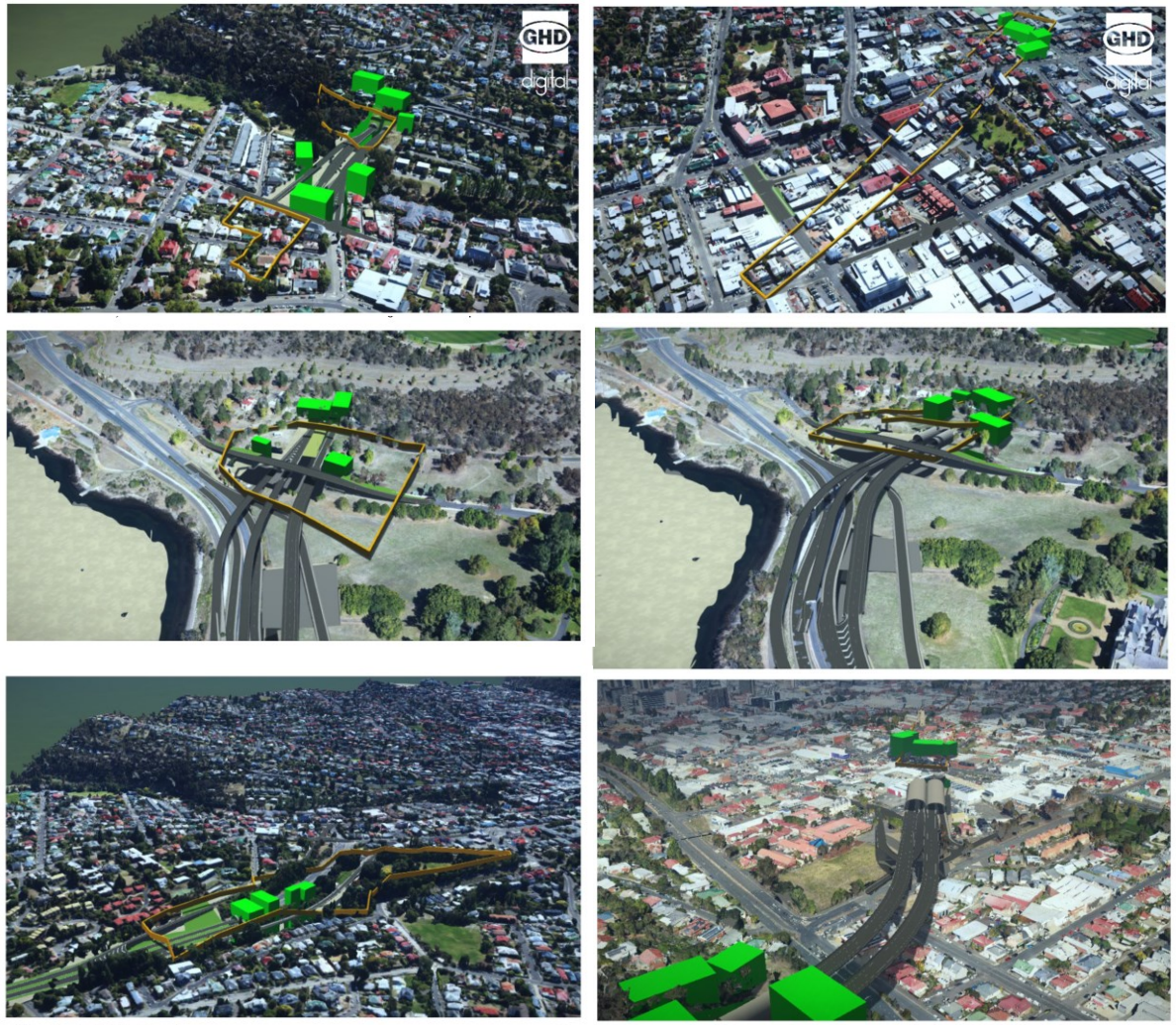
Associated Tunnel Surface Infrastructure

Tunnel Portals - Traffic Interchanges and Ventilation Infrastructure

Very signifiant surface impact

Brisbane Airport Tunnel Portals and Interchange



GHD Visualisations of Surface Infrastructure – Tunnel Feasibly Study

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This Presentation

What do we actually know about the geology beneath Hobart?

What information do we have to properly evaluate proposals for major civil works such as tunnels and underground carparks in Hobart?

Can reasonable geological models be created for the sub-surface of Hobart?

What details of the geology might need to be understood to inform any detailed tunnel feasibility study? Or any other major future civil works that may be proposed for the city area

It is the result of a recent in-depth review of the geology of all of the state capital CBDs, which highlighted how little is actually known about the geology beneath our cities (at least in the public domain)

What is my interest, and background to this?

This work forms part of a larger study of the geology beneath Australian state capital CBDs – with the aim of developing 3D geological models

It is research for a book on the geology of Australian cities

Hobart Geology

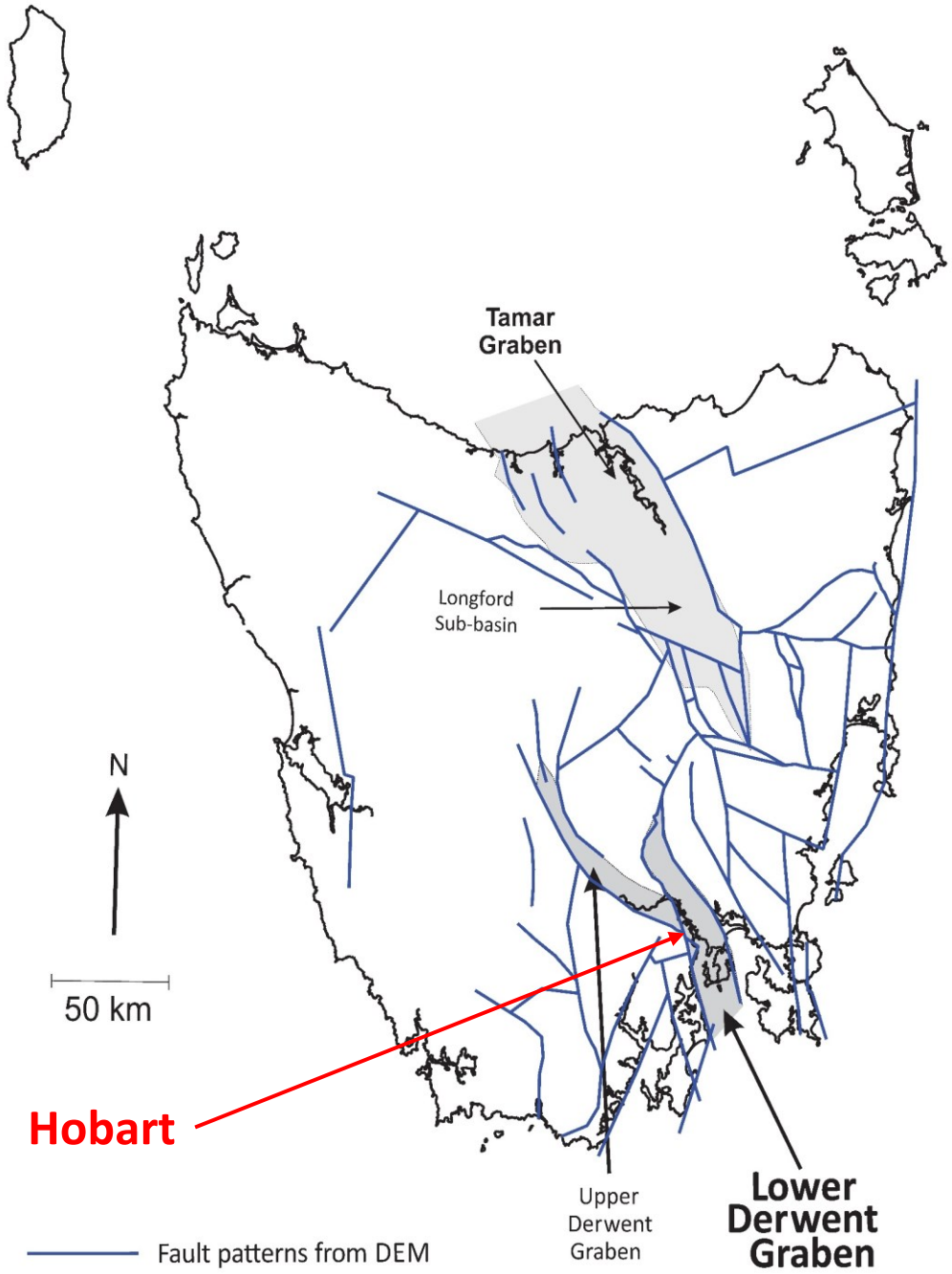
- As Australia broke away from Antarctica during the final stages of the dismemberment of Gondwana (Late Cretaceous, from 95–85 Ma), deep rifting scars were left in one of the last remaining links between the two developing continents. This small crustal fragment would become the island of **Tasmania** (*Blewett 2012*).

- Throughout the Cenozoic, the rift graben scars became the focus of drainage from highland glaciers, creating deeply incised river valleys that were eventually drowned during the last post-glacial marine transgression between 20,000- and 6000-7000-years BP (*Harvey and Caton 2010*).

- The **River Derwent and its estuary** occupy one of these structurally complex belts of faulted rocks, the Lower Derwent Graben, which have been extensively deformed and down-dropped, creating a stepped graben *(Stacey and Berry 2004).*

- The river exploited the deformed, structurally weakened and more easily weathered and eroded rocks to form the deeply **incised River Derwent Valley**

- Hobart lies on the western shore of the valley, which is also at the western margin of the **Lower Derwent Graben**



Late Jurassic to Middle Tertiary basins and fault patterns interpreted from the high resolution DEM. Modified after Stacey and Berry (2004)

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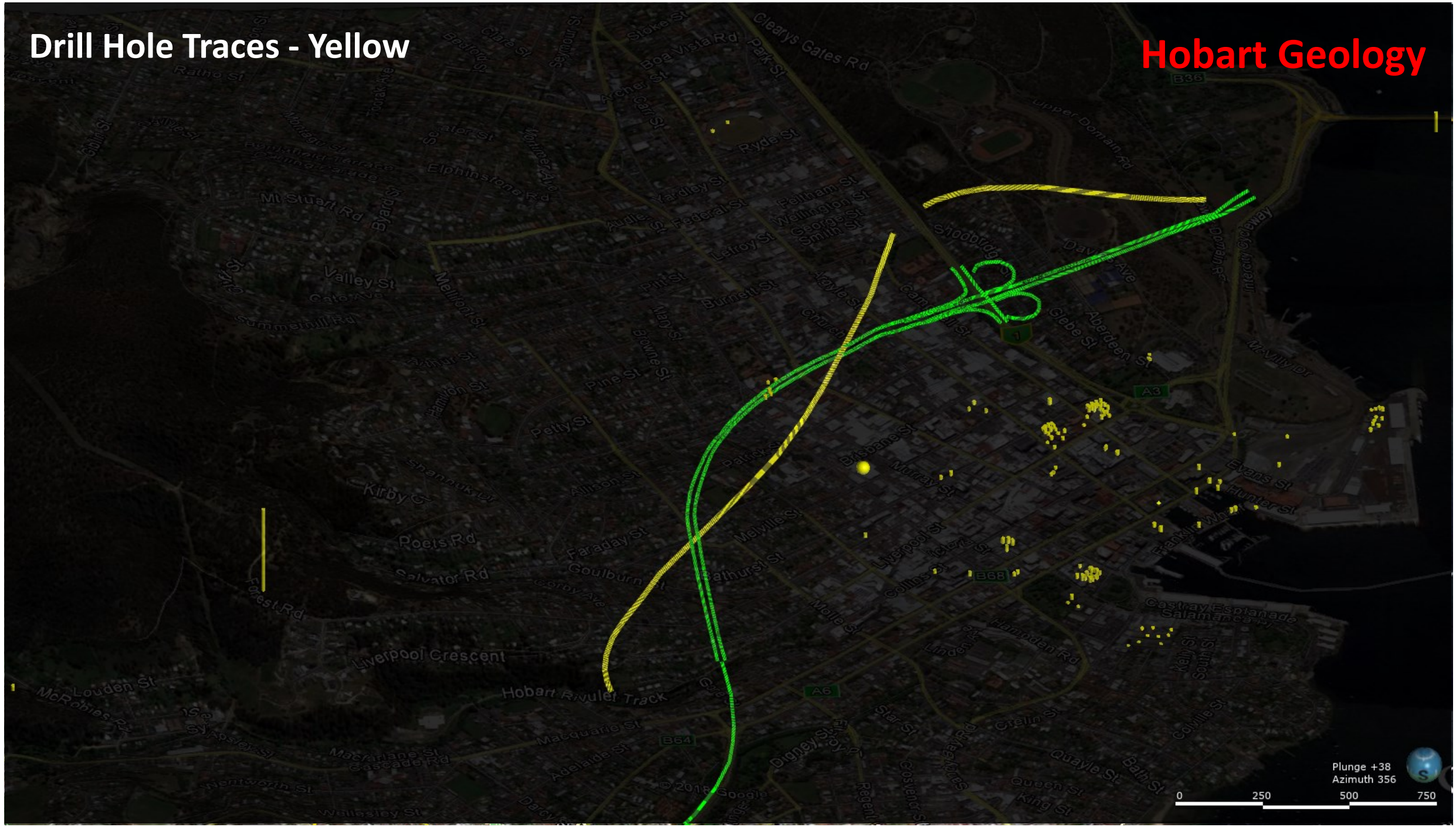
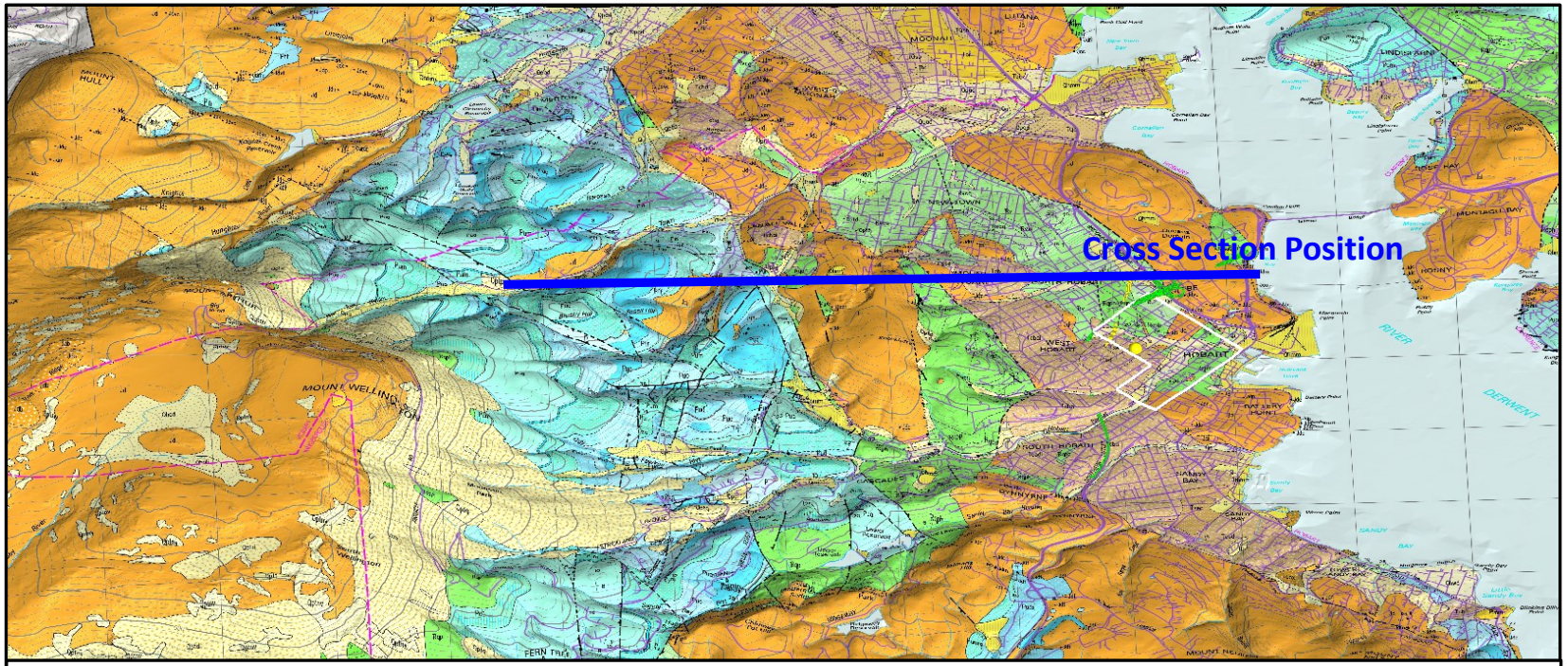
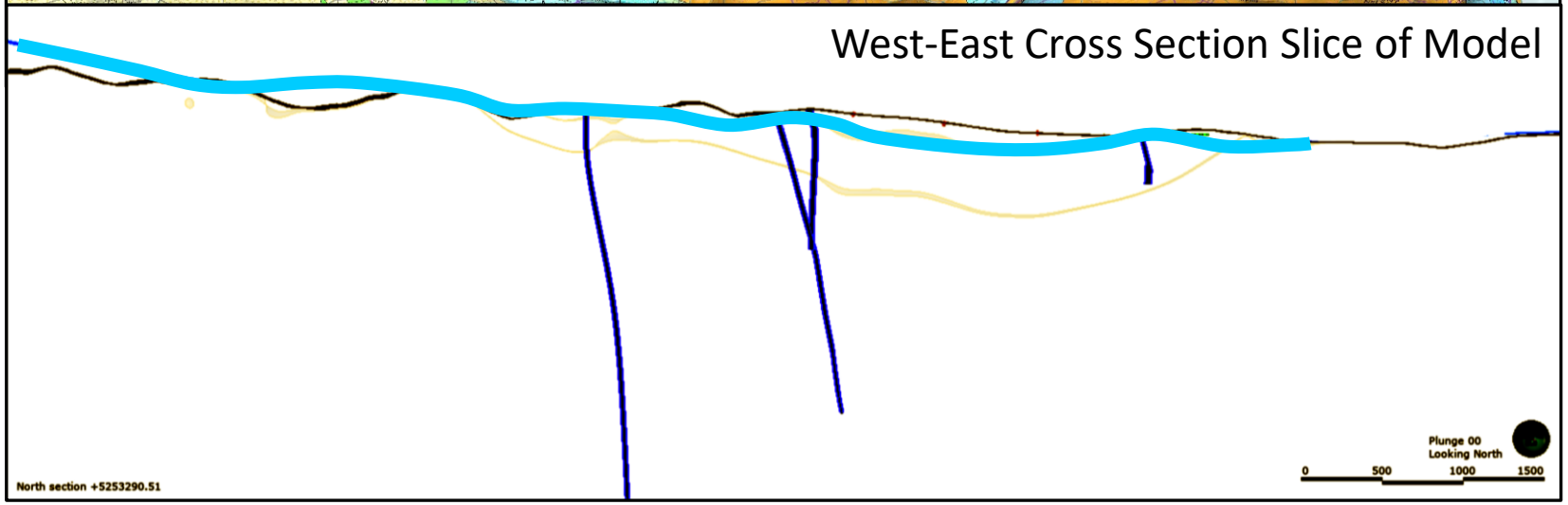

Drill Hole Traces - Yellow
Hobart Geology
Plunge +38
Azimuth 356
0
250
500
750

Hobart Geology - Permian Sedimentary Rocks

Oldest Rocks in Hobart Area.

- Permian - glaciomarine (marine and freshwater) sedimentary siltstones and sandstones (with some argillaceous limestone) - f the Lower Parmeener Supergroup (Forsyth and Clarke 1999).
- Don't outcrop in the city area.
- Form the high ground to the west - foothills and lower slopes of Mount Wellington,
- They **lie beneath the city area**, probably just below a largely stratabound dolerite sill that has intruded along the Permo-Triassic contact.
- They are generally of a very low dip angle and are probably gently folded along c N-S axes
- The upper boundary with the triassinc sediments may occur at the level of the proposed tunnels





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Hobart Geology - Triassic Sedimentary Rocks

The city area is mostly underlain by downfaulted and folded, younger freshwater Triassic sandstone, siltstone (with some mudstone) of the Upper Parmeener Supergroup.

- The Triassic sandstones are an important influence on the city area landscape. They underlie most of the low ground of the floor of the linear '**Hobart Valley'**, which parallels the trend of the down-faulted block of sandstone on the western margin of Lower Derwent Graben. In the city area, Triassic sandstone formed low cliffs and the steep banks of the Hobart Rivulet, as well as stepped waterfalls and pavement outcrops in the stream bed further west, which became known as the 'cascades'

- The sediments are more easily eroded sandstone underlying the central CBD formed a NW-trending (fault-bounded) valley, along which the CBD spreads

- The Triassic rocks form **a relatively thin veneer** above the contact with the Lower Permian sediments, but particularly above the dolerite sill that intrudes the Permo-Triassic boundary

An important assumption made in the recent tunnel proposals is that much of its course would be in Triassic sandstone. This is unlikely to be the case.

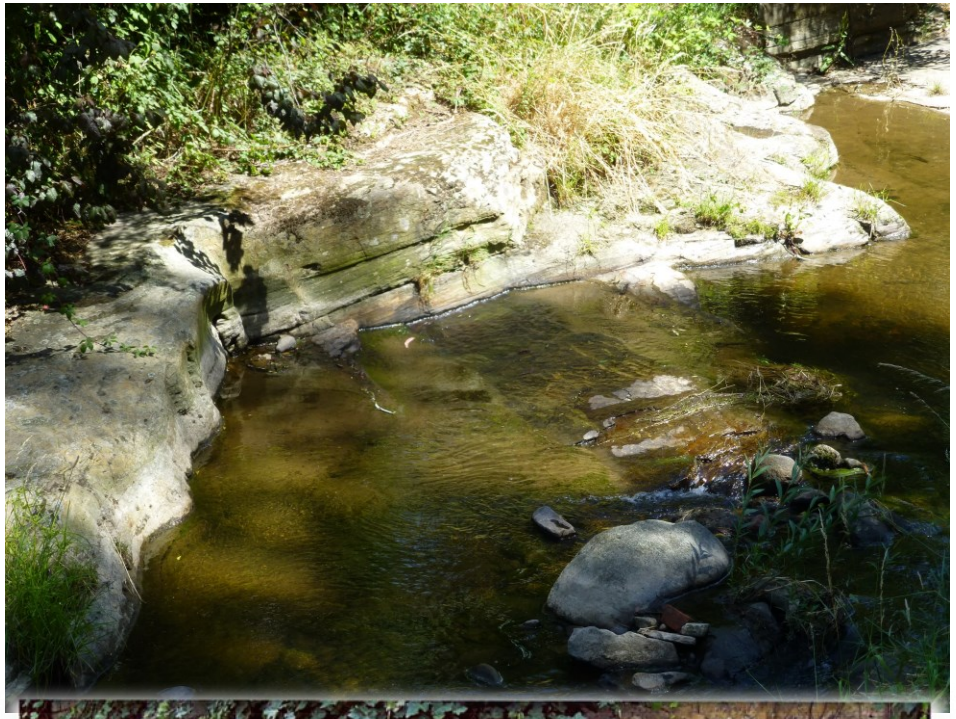

Photo of Triassic sediments at the Tasmanian Museum, by Tony Hope taken in February 2005 (Hope, 2012)

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Hobart Geology - Jurassic Dolerite

Most higher hills of inner Hobart are formed by Jurassic dolerite, intruded as sills and dykes in the Permo-Triassic sedimentary sequence.

- There are two or three major sills in the Hobart area, ranging in thickness from 1 m to 300-400 m.
- The sill forms the linear ridge of the Queen's Domain and Macquarie Point to the east, and Battery Point and Barracks Hill to the south. Jurassic dolerite also formed Hunter Island.
- The sedimentary rocks are contact metamorphosed for a few meters beyond the sill margins, with the greatest effects in the roof (*Leaman 1975; Stacey and Berry 2004*).
- Sub-horizontal joints are common within the dolerite
- There is internal mineralogical and textural variability; from massive glassy to coarse-grained etcetera,
- **Weathering** – little is known about the extent of weathering in the dolerite or if there is deeper weathering along joints and faults within it. Hofto, et al., (1991) noted that " weathering is dependent on joint frequency and direction, causing a variation in rock strength both vertically and horizontally".
- Weathering pattern/level could vary according to dolerite mineralogy and textural type (as is seen at surface)

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Hobart Geology - Jurassic Dolerite cont'd

Jurassic Dolerite Forms Large Sills

Preliminary 3D modelling of the Hobart area suggests that the dolerite sills can be correlated across the city area

They are stratabound - particularly at the Permo-Triassic boundary in Hobart

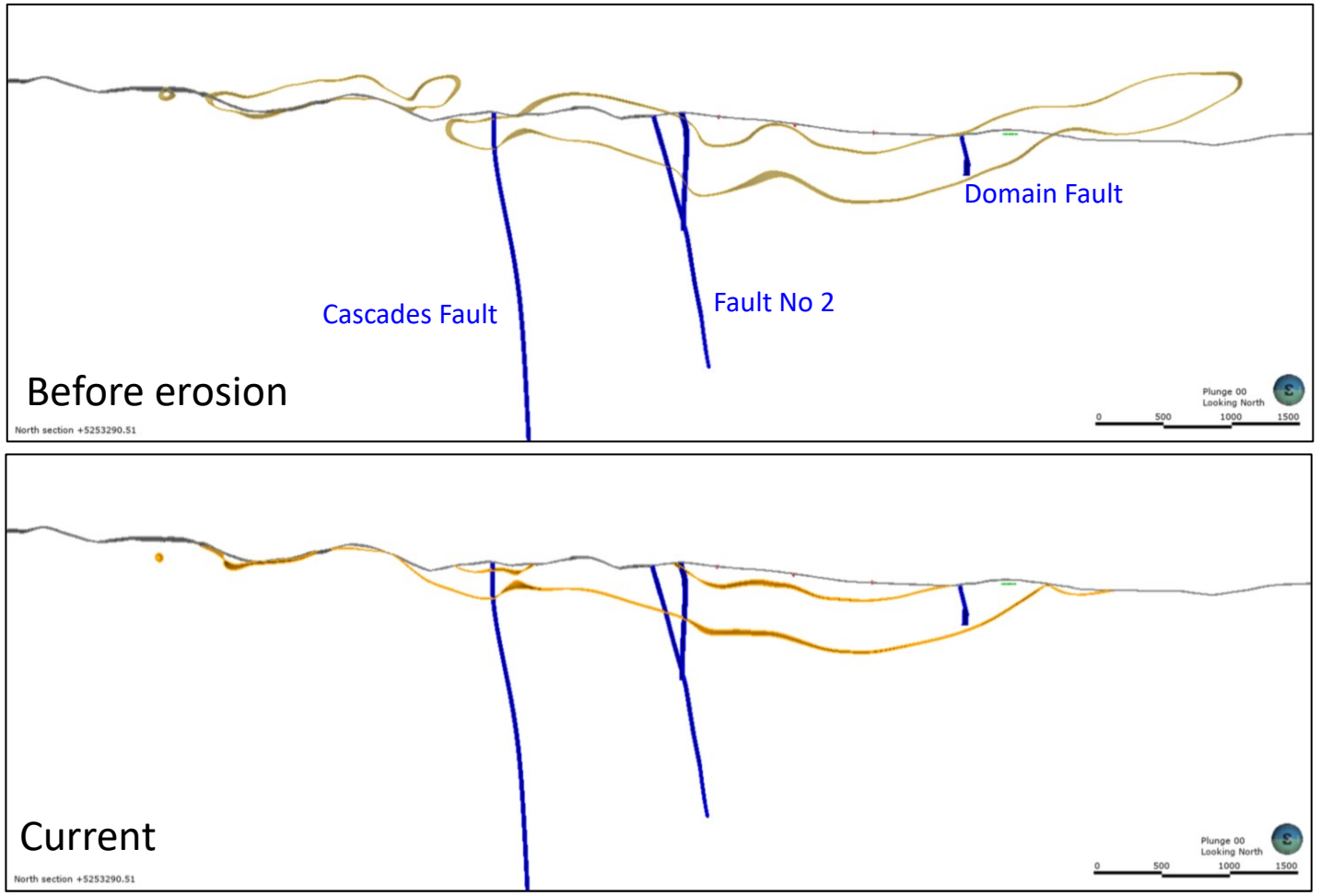
The main sill in the city area (of likely variable but unknown thickness) intruded along the Permo-Triassic boundary

It has been broadly folded and faulted with the encompassing sediments, with the folded geometry of the sill creating most of the important hills in the city area - where the stratabound sill in the fold limbs intersects the surface

- If this interpretation is correct, then large volumes of dolerite would lie at depth, just below city centre, and in the tunnel area
- Tunnelling might have to either negotiate long runs of dolerite, or the metamorphosed and jointed rocks along their upper intrusive contacts

Any tunnel in the CBD would likely run sub-parallel to the low-angle, undulose upper contact of the sill, and any contact metamorphism of the overlying sedimentary rocks (including vertical columnar jointing). It may be required to pass across the contact zone more than once. So tunnels that intersected the upper contacts of sills could have to deal hard rock, with complexly vertically jointed weak rock above

Even **small offshoots and dykes of dolerite** could be problematic for large scale tunnelling and excavations, as shown by the Lane Cove Tunnel collapse in Sydney. Knowing the locations, geometry and weathering state of even very small intrusive bodies needs to be understood for tunnel excavations.



East-west cross section slices of the 3D geological model showing the interpretation of the dolerite sill beneath central Hobart (orange). View is to north. Section is approximately through Mt Stuart. The upper image shows the geometry before erosion

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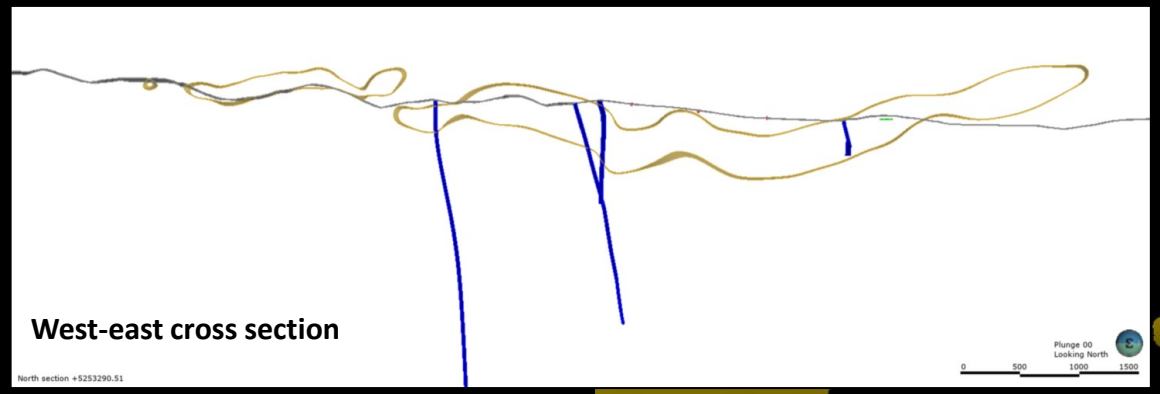
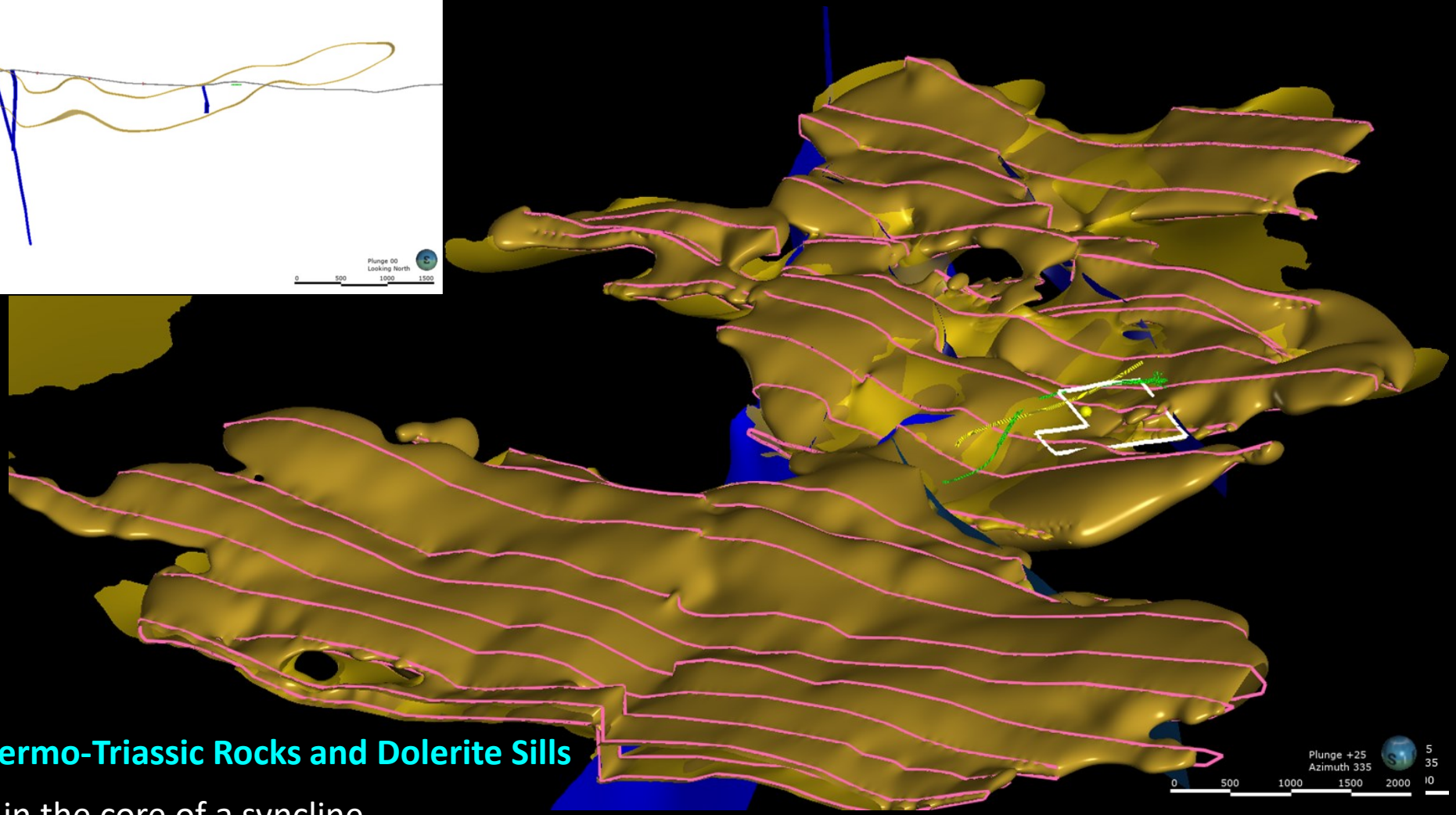
Hobart Geology - Folding





Gentle Open Folding if Permo-Triassic Rocks and Dolerite Sills

Hobart lies in the core of a syncline

Dolerite sills are folded with the strata

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Hobart Geology - Faults

The sequence of rocks beneath Hobart is **heavily dissected by Late Mesozoic faulting** associated with the western margin of the Lower Derwent Graben.

Hobart is **not** seismically active, despite the extensive faulting the occurs throughout the Hobart area.

Cascades Fault Zone:

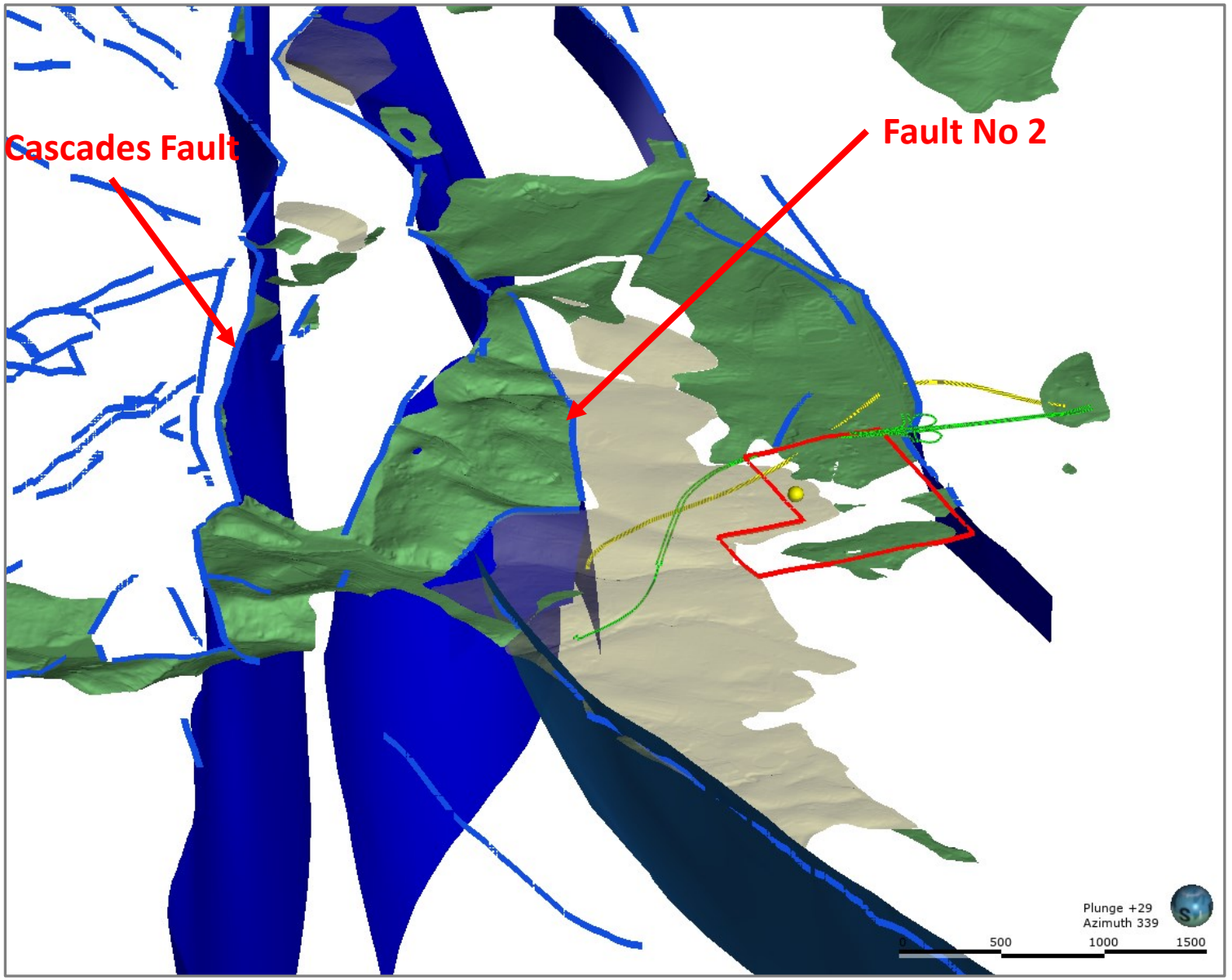
- The Cascades Fault Zone is the most important fault system in central Hobart.
- Defines the western margin of the graben.

Forms the structural boundary between the older upthrown Lower Parmeener Supergroup rocks forming the rising ground to the west, and the younger Triassic rocks that underly the central Hobart (*Forsyth and Clarke 1999*)

Domain Rivulet Fault: Though inactive, these structures will represent belts of deformed rock and poor ground requiring support; conduits for deeper weathering, and for ground water.

The trend of the tunnels. As proposed in the recent feasibility study by Council

Fault No 2: An equally significant fault? With a scarp associated with the "Boulder Beds"



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Cenozoic Boulder Beds

The Parmeener Supergroup and dolerite is mantled by Cenozoic boulder deposits and talus slopes comprised of varying proportions of **poorly consolidated boulders and cobbles** of sedimentary rock and dolerite in a sand to silt matrix.

The boulder deposits have been shed from the flanks of the higher ground to the west, including Mount Stuart and Knocklofty, and probably formed during periglacial conditions of the last ice age.

The boulder beds underlie most of the western side of the study area, including the modern suburbs of West Hobart and South Hobart (*Forsyth and Clarke 1999).*

Aspects of the Boulder Beds that Could Impact on Tunnelling

- Basal surface (palaeotopography of the unconformity) – the geometry of this surface would need to be understood because it could be intersected by any tunnelling, particularly at the western end.
- The degree of weathering and level of consolidation (lithification) of the boulder beds
- The dolerite and sedimentary rocks masked by the boulder deposits may be significantly weathered (and weaker)

Figure 3 Boulder beds consisting of soils and large boulders are common under Hobart and problematic for tunnelling. Source: Mineral Resources Tasmania

Available Information - Geological Mapping

Geological Maps & the CBD

Hobart is well-served by high quality 1:25,000 scale geological mapping.

- This is a better situation than most other Australian capital cities.
- No Australian city has publicly available mapping at such a scale. Most geological maps for other Australian CBDs date to before the 1980s

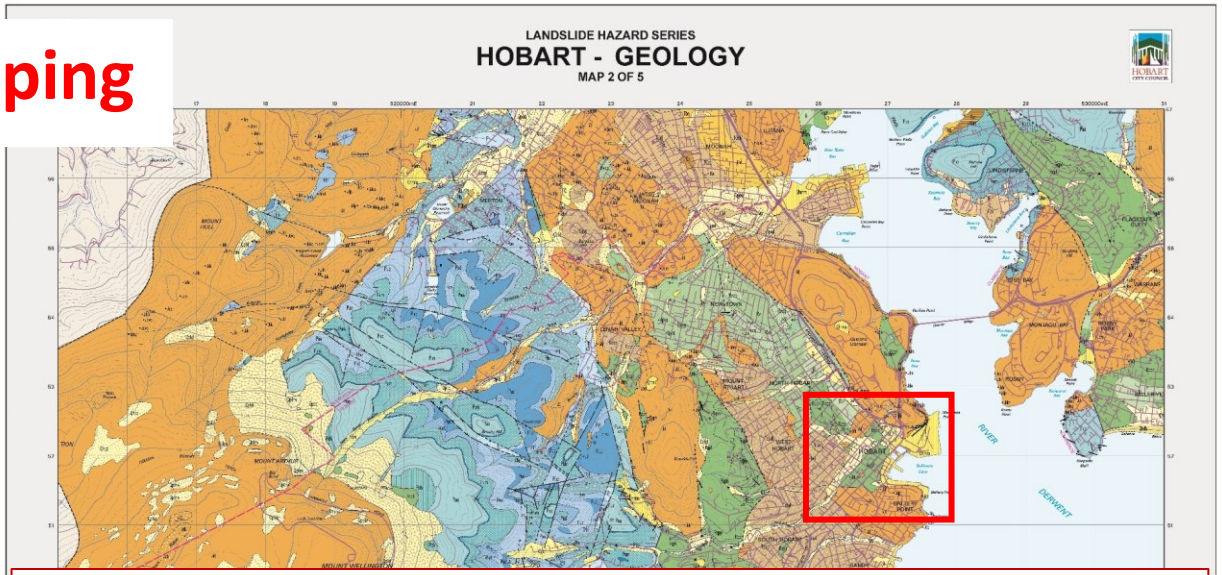
However, when we talk about geology maps, we are normally referring to huge areas of the crust. Strangely, when we discuss the CBDs of cities such as Hobart, we are really discussing tiny areas.

And even the Hobart geology map does NOT really provide the detailed information that planners need for urban developments, such as the Hobart tunnels.

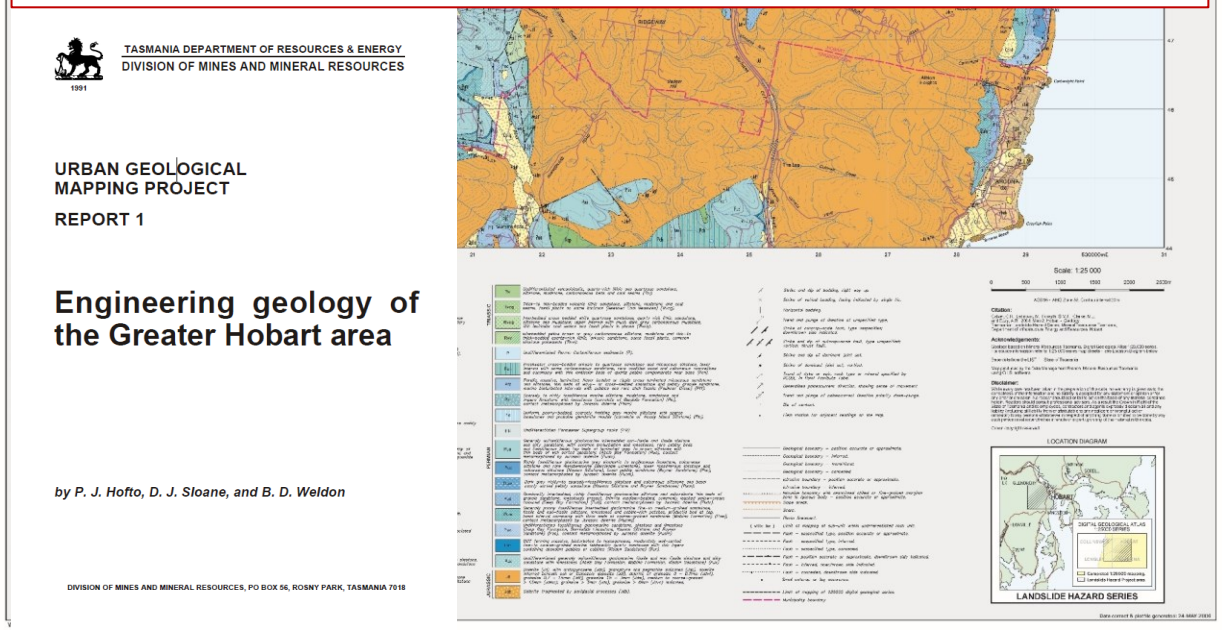
BUT: There are no sub-surface 3D geological models in the public domain

There is also other geoscientific information:

- *Engineering Geology Study – Greater Hobart (Hofto, Sloane, and Weldon, 1991)*
- *Land slip prediction and tsunami studies*
- *Flood hazard prediction maps*
- *Aerial / satellite Imagery*
- *Geophysical data (old?) and particularly **LIDAR***



However, the mapping does seem to be good enough to create a broad-scale 3D geological model. This makes if more useful as the basis for feasibility studies. But more detailed mapping and drilling data is still required to assess any major tunnel construction proposal



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Available Information - Drill Hole Data

Drillholes

My project is to add the lithology by individually accessing scanned logs and entering the from to depths into a lithological (and structural) data file for use in 3D modelling

- **But they don't have lithology**

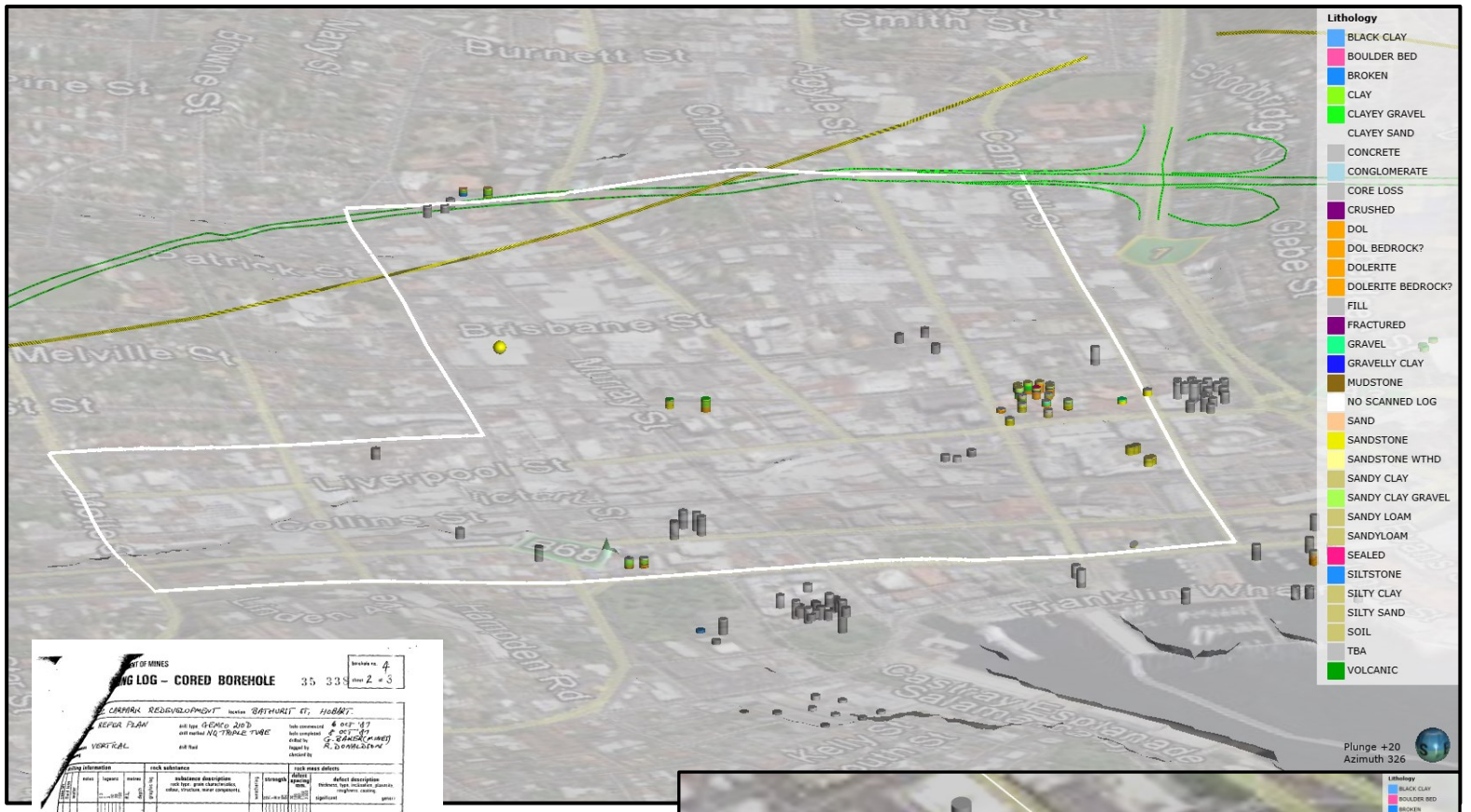
Deepest in inner city area:

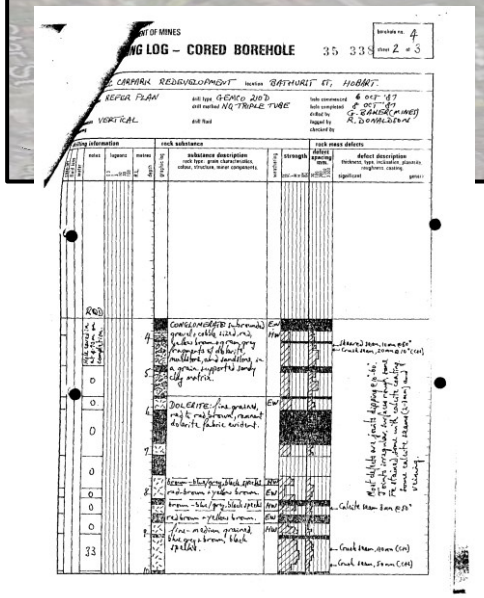
- The drillhole in the CBD are shown at right
- KNO-1 – Knocklofty = 298 m; LV-1 Lenah Valley = 247 m; Porter Hill (Grange) = 194 m – all have no log available but core held at Mornington
- Most drilling predates the turn of the 21st century
- Links to individual holes take you to a scanned log, if it exists

Available from MRT

Other data exists (e.g. HCC) but not publicly available and was not made available to MRT – so MRT records must be incomplete

There is presumably other data held by consultancies





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Summary

Some Key Geological Features that we Probably Need to Know (at Least Along Any Proposed Tunnel Corridor)

1. The location (depth) and geometry of the upper contact of the gently folded dolerite sill directly beneath Hobart CBD
2. The orientation of any jointing within the sedimentary rocks in the contact metamorphosed zone above the upper contact – are there columnar sets of vertical joints present?
3. The position of the upper contact of the Permian and Triassic sequences (and its interactions with dolerite)
4. The strata within the Triassic Sediments – particularly the locations of mudstone & tectonised units.
5. The palaeotopography at the bottom of the boulder beds
6. The locations of major and minor faults (and joint sets) and their damage zones
7. The degree of, and depth of weathering penetration along major and minor faults (particularly the Cascades Fault Zone, but also the others) and joint systems
8. The depth of weathering and its variability in different rock types
9. Jointing in the dolerite – are there horizontal joints? Patterns in the more deformed parts of the sill beneath the city
10. The location and geometry of any smaller dolerite dykes and sills forming offshoots of the main sills (and their degree of weathering).
11. The mineralogical zonation of the dolerite (as a layered sill) and if weathering effects different zones more than others, and in different ways (e.g. massive glassy dolerite vs onions skin weathering, red gravel generating etc)

Conclusions

The Original Questions

What do we actually know about the geology beneath Hobart?

Virtually nothing in any detail

The greatest depth tested by drilling information is just over 15 m – except for three holes – e.g., 250m – in Lenah Valley, Knocklofty and Porter Hill (nowhere near the CBD). Only a small cluster of five or so holes lies within the proposed tunnel corridors

What information do we have to properly evaluate proposals for major civil works such as tunnels and underground carparks in Hobart?

Really only 25K mapping (as good as it is)

Limited and patchy drilling data – but almost none near proposed tunnel corridors

Can reasonable 3D geological models be created for the sub-surface of Hobart?

Yes, but just barely. We can start to generate 3D geological models for the substrate but they are of very low reliability, with no drilling to calibrate surface mapping data, and no information is available about the width and orientation of fault zones

Having said that, new structural and stratigraphic understanding of the geology of the Hobart region may be possible from these low reliability geological models

The geological information is not available beneath Hobart to make any realistic, even preliminary assessment of the geological conditions that would be encountered by any large underground infrastructure projects.

The Hobart example highlights the lack of geological information there is available beneath Hobart (at least in the public domain) to adequately evaluate such tunnel proposals

This calls for better urban geology information in Hobart

This lack of sub-surface geological information in the public domain is also an issue in other Australian capitals

Urban geological information in Australia is virtually non-existent