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Field Trip Guide – Geomorphology and natural hazards on kunanyi/Mount Wellington

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Introduction

This field guide serves as background notes for the post conference excursion. This is an opportunity to have a break from the lecture room, enjoy some Tasmanian scenery, get some exercise and test your field skills. Almost all of the walking will be downhill but be careful as the tracks are steep and uneven!

The impressive mountain behind Hobart is known as kunanyi by the indigenous people who have lived in Tasmania for more than 40 000 years. It has more recently been named Mount Wellington by the British after Arthur Wellesley, aka the Duke of Wellington, who they credit for defeating Napolean Boneparte in 1815. Most recently the Tasmanian Government has officially recognised the original name and a duel naming policy now applies.

Today this mountain is a popular tourist destination and a recreational park for walkers, mountain bikers, rock climbers, etc. Currently, there are plans for a cable car and new visitor centre to be built on the mountain; something that has the community divided. For us as geotechs it also has some impressive rock formations and mass wasting features to savour. Furthermore, there is a history of landslides that pose a threat to users of the park and settlements at the base of the mountain.

The view from the lookout on the summit is impressive on a good day and I am hoping it will be today. At 1270 m elevation, the summit can also be a hostile environment for visitors, with snow falls and blizzard conditions known to occur regardless of season. Today's walk, subject to weather, will take us from the summit down walking tracks to the Chalet, where we will meet the bus. On the attached field map (Figure 1) we will follow the South Wellington Track from the Summit, then branch onto the Zig Zag Track down to the intersection with the Pinnacle and Organ Pipes tracks. Here we turn right onto the Pinnacle Track and walk about 100m till we meet the 2014 rock fall boulder. After this stop we backtrack to the last intersection and the follow the Organ Pipes Track all the way to the Chalet. It is not a long distance and not a race. One needs to exercise care along the path and I would encourage you to note the changes in the landscape as you descend. There will be stops at a number of locations along the way so please do not overtake the designated leader! Please also respect other users of the track.

Geological Setting

The upper parts of the mountain comprise two main bedrock units:

Upper and Lower Parmeener Supergroup approximately corresponding to Permian and Triassic ages respectively.

These sequences comprise sub-horizontal sedimentary units of shallow marine and freshwater origin including sandstones, mudstones, conglomerate and coal seams. The base of the Upper unit roughly corresponds to the Permian -Triassic boundary when one of the largest extinction events in Earth's history occurred. This event was possibly related to an asteroid collision and ultimately led to the rise of the dinosaurs.

Similar sedimentary units to the Parmeener occur along the eastern margin of Australia, including the major coal fields (that currently underpin the nations' economy) and represent erosion of mountains and sedimentation in widespread basins in a post-subduction environment. For those familiar with Sydney, the impressive Hawkesbury Sandstone outcrops has an equivalent in the Tasmanian sequences.

Tasmanian Dolerite Formation of Jurassic age.

This is a somewhat enigmatic unit that is almost entirely restricted to the Tasmanian part of the Australian continent, but also occurs in Victoria Land (Antarctic), South Africa and two small occurrences in the South Island of New Zealand. It is believed to represent a mantle upwelling and intrusion into the Gondwana continent, prior to its breakup. The dolerite is intruded within the Parmeener rocks, but because it is relatively more erosion resistant than the latter, it commonly forms upstanding plateaus or razor back ridges in the landscape. There is one known locality in Tasmania where the molten lava reached the surface to erupt and form basalt flows.

[As a reminder, dolerite and basalt have similar chemistry but different texture; dolerite has coarse crystals visible to the naked eye because it cooled slowly allowing crystals to grow; whereas basalt was rapidly cooled and most of its crystal structure requires a microscope to resolve.]

Today you will see the impressive dolerite columns that form the Organ Pipes cliff where fresh rock is evident. However, there are also places where the weathering processes have reduced the rock down to soil strength. Unfortunately, the distribution of these areas is poorly understood yet it is vitally important to understand landslide processes.

Subsequent geological evolution

In Cretaceous times the bedrock sequences described above were uplifted and eroded, possibly associated with Gondwana breakup. This breakup included the creation of the Tasman Sea through sea-floor spreading, a process that extended into the Paleogene. Tectonic extension stretched the Tasmanian crust and led to the formation of grabens and half grabens (failed rifts) and associated basins that have had a profound impact on drainage development and landscape form in eastern Tasmania.

Most of the principal drainage one can see from the summit actually formed in Cretaceous- early Cenozoic times indicating an old landscape; as compared with most of New Zealand. We know this because there was a phase of terrestrial basaltic volcanism in the Paleogene (Early Cenozoic) where lava flows infilled paleo-valleys not much higher than the current base-levels of the present day river channels. In our walk today we will pass close to a small volcanic neck related to this volcanism at the beginning of the Zig-zag Track. In addition to the Bedrock units described above, slope deposits including periglacial features mantle the flanks of the mountain and much of this trip will be directed toward looking at these units.

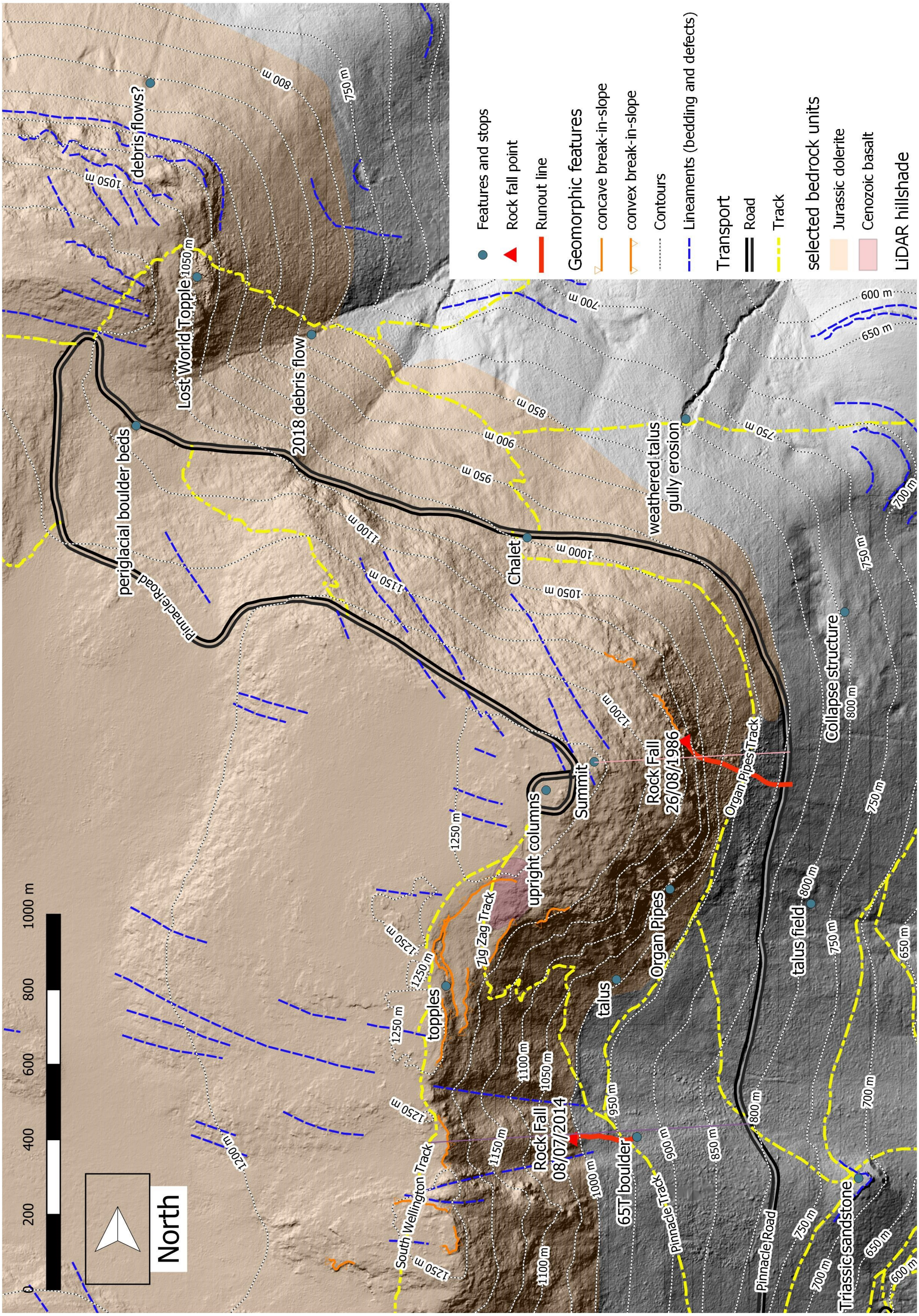

Figure 1 Field map

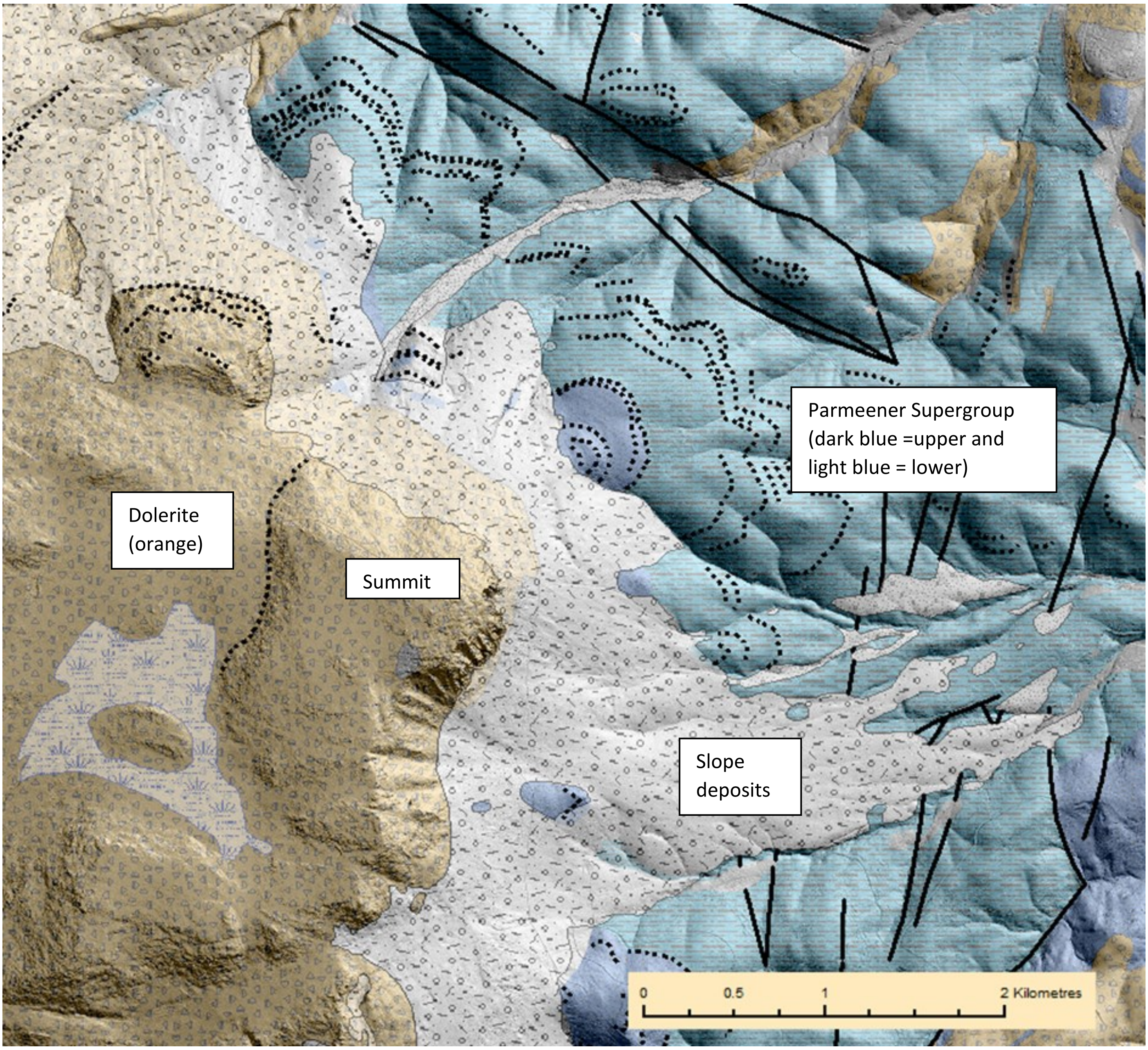

Figure 2 Simplified geology adapted from MRT 1:25 000 scale mapping

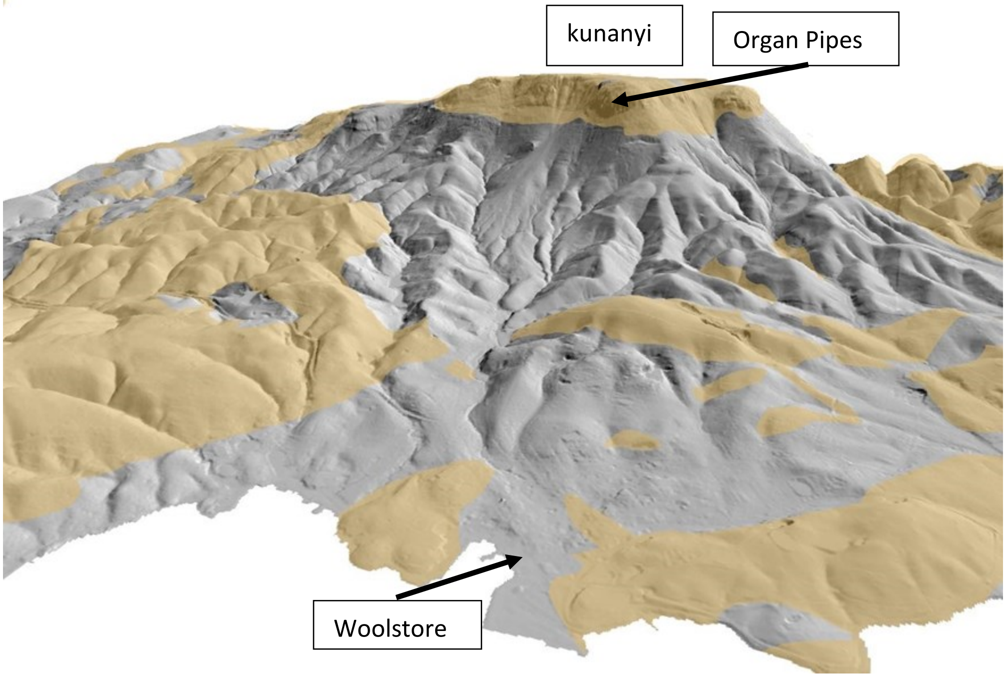

Figure 3 Distribution of dolerite in the Hobart area as viewed from the East.

Stop 1 kunanyi Summit

The view from the summit allows us to look down on greater Hobart, the Derwent Estuary and a very convoluted coastline.

Features of note:

- The Derwent Estuary is a drowned river system and during glacial periods the coastline extended many kilometers further south (to the right) than this view. If we could see the drowned channel, it would appear as an inner gorge, incised over 50 m below present sea-level. It is fascinating to think that the First Australians would have seen this very feature during their first 20 000 years of settlement in this area!
- When sea-levels rose post last-glaciation, the land bridge connecting the Australian mainland to Tasmania was submerged, effectively isolating the indigenous people from their relatives to the north. In this view below us, a number of sand spits and tombolos formed along the Holocene coastline including the airport region and the South Arm tombolo. These dune and beach ridge complexes have been a valuable source of sand for making concrete for many years, but they are a limited resource and other sources will need to be exploited in coming years.

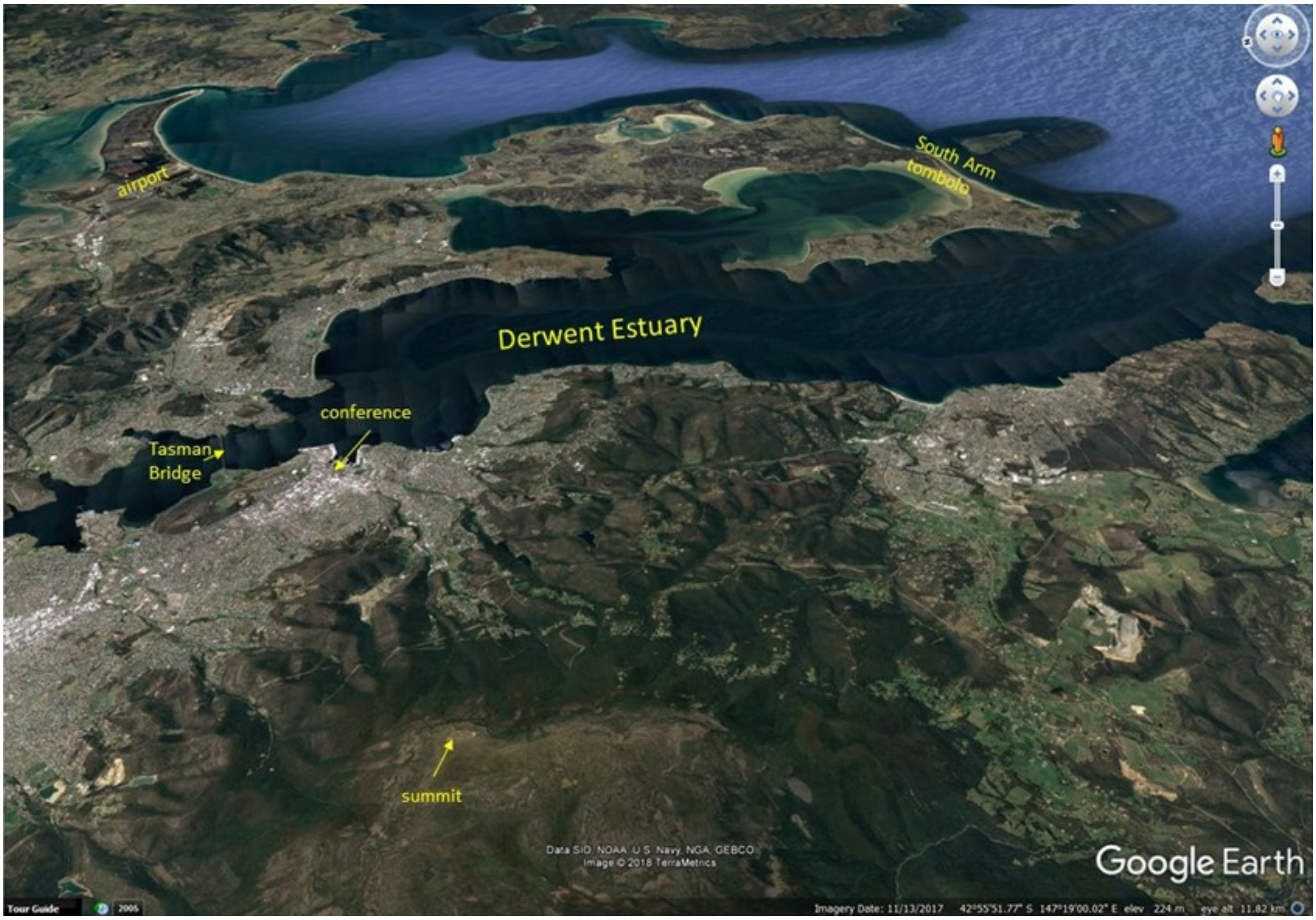

Figure 5 Google Earth view of the area seen from the summit

From the Summit along the South Wellington Track to the intersection with the Zig Zag Track

Having enjoyed the summit vista, our focus is now on the plateau landscape and the surrounding escarpment.

The plateau is a structural surface representing the approximate top of the intrusive dolerite sheet/sill; where the overlying Parmeener rocks have been preferentially eroded away revealing the more resistant dolerite mass. Originally this mass extended further east about 2 km (toward Hobart) where the escarpment initiated as the upthrown side of a major normal fault. The fault movement and hence the escarpment initiated in the Early Cenozoic has gradually retreated since then to its present position.

The plateau at around 1200 m elevation, is about 100 m above the current limit of the periglacial zone. [It can snow up here anytime in the year!]. However, in glacial times the zone was down to around 200-500 m ASL (or 600-900 m lower). While there is a broad open valley formed on the plateau, there is no evidence of any glacier having been here in the absence of morraines and other diagnostic features. The closest former glacial features lie much further inland away from the maritime influence but at similar elevations. Note that the summit is above the tree-line and here we are in sub-alpine scrub. This has important implications for rock fall processes that we will observe on the escarpment.

There are many block-field deposits scattered across the plateau that have formed on very gentle slopes as a result of periglacial processes, including frost shattering of dolerite columns and solifluction to concentrate “rubble” into local deposits. There are also instances where these block-fields extend over the edge of the escarpment onto much steeper slopes. One of these areas is marked on the field map where the Pinnacle Road crosses it near the big hairpin bend (“Big Bend”).

One of the distinctive features of the plateau are areas of slightly raised upright columns tapering upright with, in places, precarious rocks (rocking stones) capping occasional columns. These features are the result of mainly mechanical weathering along column margins and cross joints?

Figure 6 Dolerite columns with irregular weathering forms and precarious rocks on the plateau.

Zig Zag Track Segment

Our walk along the Zig Zag Track will take us past several geomorphic units that are summarised in the geomorphic process model of figure 4. Here we see the transition from the plateau onto the escarpment proper and descend to below the base of the dolerite massif.

Significant points to note:

- At the beginning of the Zig Zag Track there is a semi-circular scarp of uncertain origin. Is this the expression of a deep seated landslide or some form of shallow feature? Along this scarp there is an associated alignment of topples that have fallen consistently away from the scarp. Topple failure is a very distinctive phenomenon along the escarpment and can occur on the edge of very minor scarps such as this that leads us to speculate that this process involves ice-wedging?
- As one enters the steeper section of the track one can observe widesread topple deposits capping upright (in-situ) columns. There are a number of gullies evident that are strongly aligned with fracture patterns, some of which are depicted on the map. These gullies act as rock fall shutes with only minor shrubs to resist rolling boulders. Orange coloured sandy soils are encountered on the track forming a matrix to the surficial rubbly material. Occasional float stones of basalt will be observed near the top of the track that are derived from the adjacent Cenozoic basaltic intrusion.
- It is quite obvious that much of the dolerite escarpment is somewhat degraded and is not technically a cliff in many places (i.e. it is much less than 45 degrees slope) (Figure 14). Slope deposits are ubiquitous and it is possible to see a range of features indicative of various processes including in situ columns, topples and talus fans.

- Near the bottom of the track one crosses over the contact between the dolerite sill and the underlying Parmeener Supergroup. Unfortunately, the basal contact is obscured by surficial deposits as is the case along much of the escarpment. Surprisingly the base of the dolerite does not always form a distinct break in slope and given the widespread mantle of surficial deposits it is not easy to pick using remote sensing methods alone. The boundary as mapped is constrained by outcrop observations typically located in the many streams on the mountain. In some instances there may be a break higher up the slope from the base such as in the vicinity of the Lost World Topple (Mt Arthur area). The cause of this feature will be related to rock mass properties in some way, with the lower area more likely to be weathered and thus susceptible to soil failure mechanisms.

Figure 7 View of escarpment from Zig Zag Track.

Stop: 2014 Rock Fall Location (Pinnacle Track)

This rock fall occurred on an otherwise uneventful day; unrelated to any form of obvious trigger such as a rainfall event or earthquake. Fortunately no one was injured but some bush walkers heard it and reported it to the park managers. My colleagues and I were able to describe the feature a few weeks after the event while the evidence was still fresh (Mazengarb et al. 2015) but it is still quite obvious 4 years on what has happened. The rock fall initiated from a forward tilted toppled-block or slab (three columns wide) that lay on a steep slope in a somewhat precarious manner. The middle column has given way, probably as a result of gradual relaxation, firstly falling, then bouncing end over end, then rolling along the column long-axis crashing through sub-alpine shrubs and crossing the track before coming to rest a short distance downhill. The boulder is estimated to be about 65 tonnes in mass, has travelled a planimetric distance of 170 m with a travel angle of 27 degrees (elevation change/ planimetric distance). In our report cited above, we estimated the boulder achieved a maximum velocity of about 40 km/ hr and maximum energy of 400 kilojoules using the energy line method (Jaboyedoff and Labiouse 2011).

Figure 8 Boulder of dolerite with Pinnacle Track in foreground.

In comparing the travel angle of this event with those summarised in the Jaboyedoff and Labiouse paper, it suggests that is in the extreme end of the range having run out further than 99% of their distribution (Figure 10).

Figure 9 Example of forward tilted blocks of dolerite behind person similar to the 2014 rock fall event,

I have also trialled the Rockyfor3D software to model the runout distribution in a Monte Carlo type simulation. This software estimates an area and probability distribution, with our 2014 event sitting in a 1-25% position (Figure 11). Interestingly, a very small percentage (<1%) of simulations crossed the Pinnacle Road.

Note that where the rock fall has crossed the track, there are pale clays exposed that are derived from the Upper Parmeener sequence.

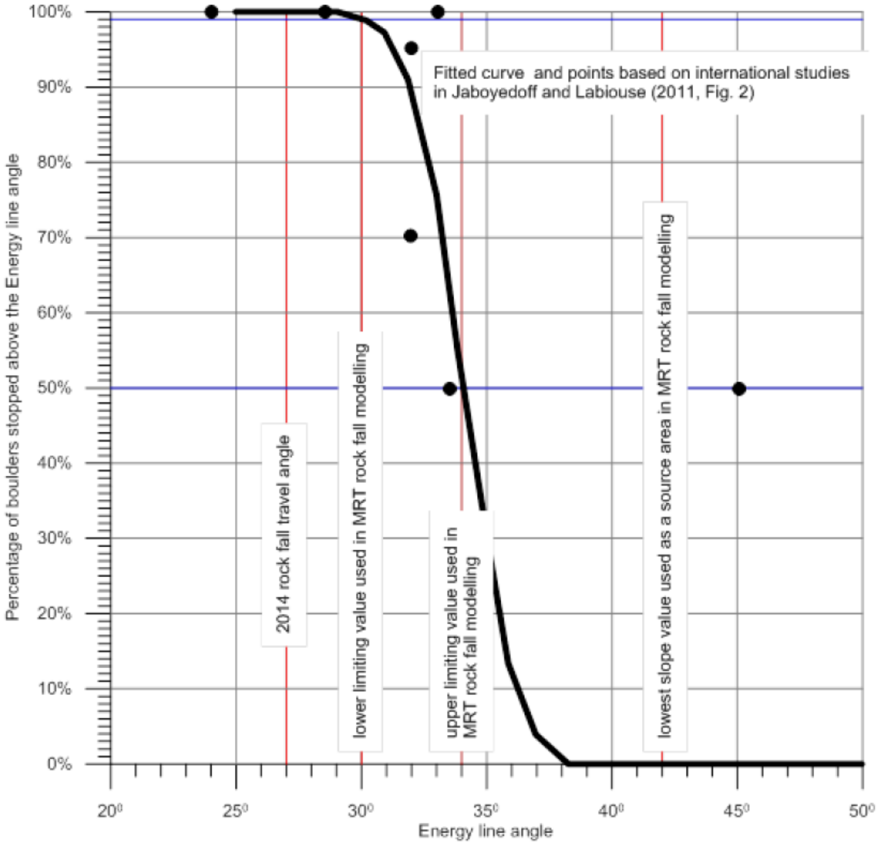

Figure 10 Parameters used in MRT rock fall runout modelling as compared with those in international studies summarised in Jaboyedoff and Labiouse (2011). The 2014 Mount Wellington rock fall is also shown.

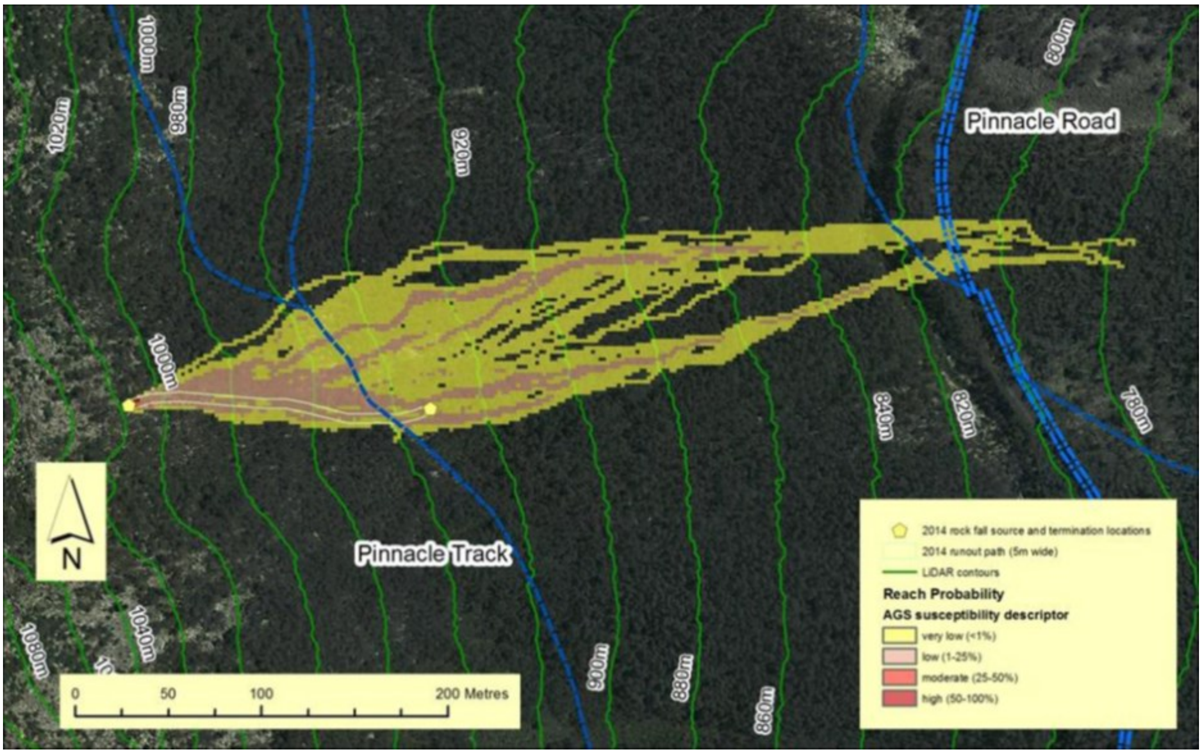

Figure 11 Rock fall reach probability using the Rockyfor3D software. Note that Moderate and High susceptibility areas are restricted to the vicinity of the source area

Organ Pipes Track Segment

The Organ Pipes segment of this field trip takes us along talus fields and past the most impressive of the cliffs on the escarpment. It is a popular area for rock climbing and for those like us on foot who marvel at nature. It may soon also have a cable car passing over it subject to planning approval. The Organ Pipes as the name suggests describe the very steep bluff section ~100 m high, exposing vertical cooling columns within the dolerite formation. Such features are common in mountain areas (and along sea cliffs up to 300m high) in Tasmania and are usually paired with talus fields below. Rock fall and toppling are probably the most dominant mass-wasting process operating on the bluff in the present warm climate. In detail there are several causal factors for the instability of individual columns including the presence of ubiquitous sub-horizontal joints that predispose them to failure. There are likely to be several mechanical processes at work, including diurnal thermal effects, ice heaving and chockstone effects (debris wedging). Peter Stevenson (1980) provided a useful discussion of the types of rock fall and topple failure on the mountain with one of his figures included in this guide (Figure 13).

At a bigger scale, slab failure (involving rows of columns) is another mechanism of failure, similar to what has occurred at the nearby Lost World Topple and around parts of Ben Lomond in the North of the State. Given the striking difference of the Organ Pipes to the areas north and south along the escarpment (e.g. Figure 14) could the origin of this scarp have been caused by slab failure?

Most of the Organ Pipes Track is situated on the talus deposits that have formed beneath the escarpment. These deposits consist of relatively fresh boulders mainly accumulated by rock fall and toppling processes. There is no or little matrix evident separating the boulders on this track and the deposits are probably well below their angle of repose. However, below the road, immediately downhill, is a large structure within similar deposits that suggests some form of collapse has occurred. The morphology of this feature has the appearance of nivation structures, associated with snow and ice and presumably related to cooler Pleistocene climates.

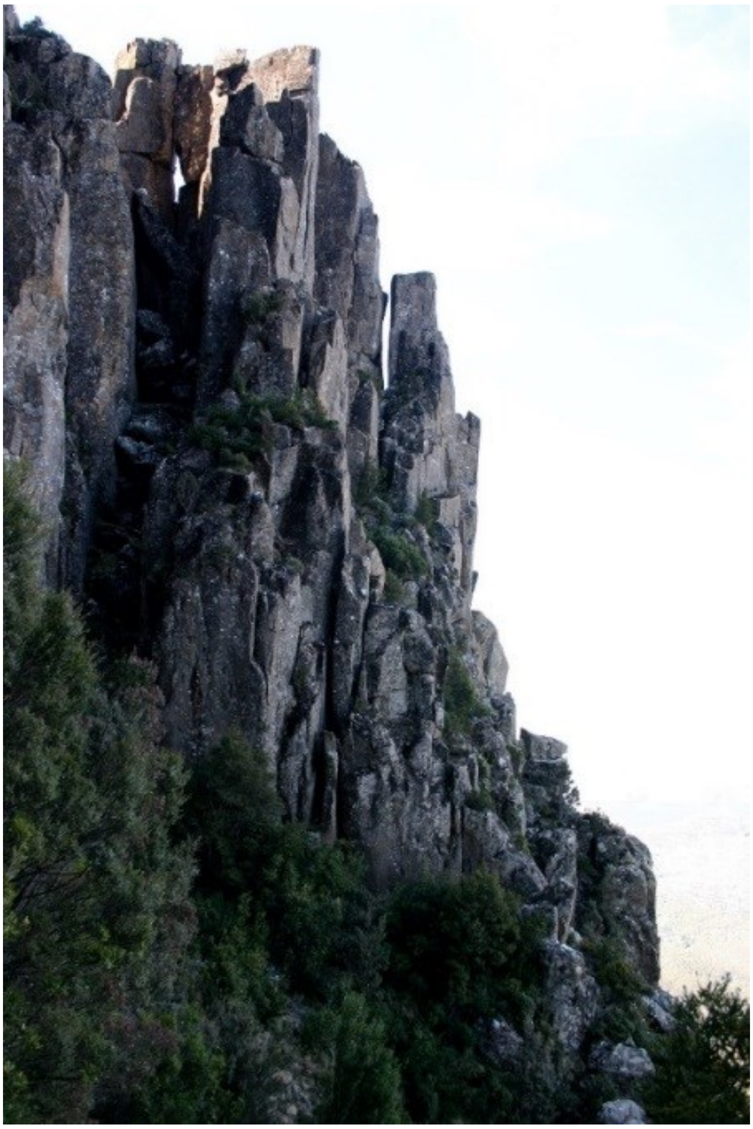

Figure 12 Chockstones forcing columns apart on the Organ Pipes

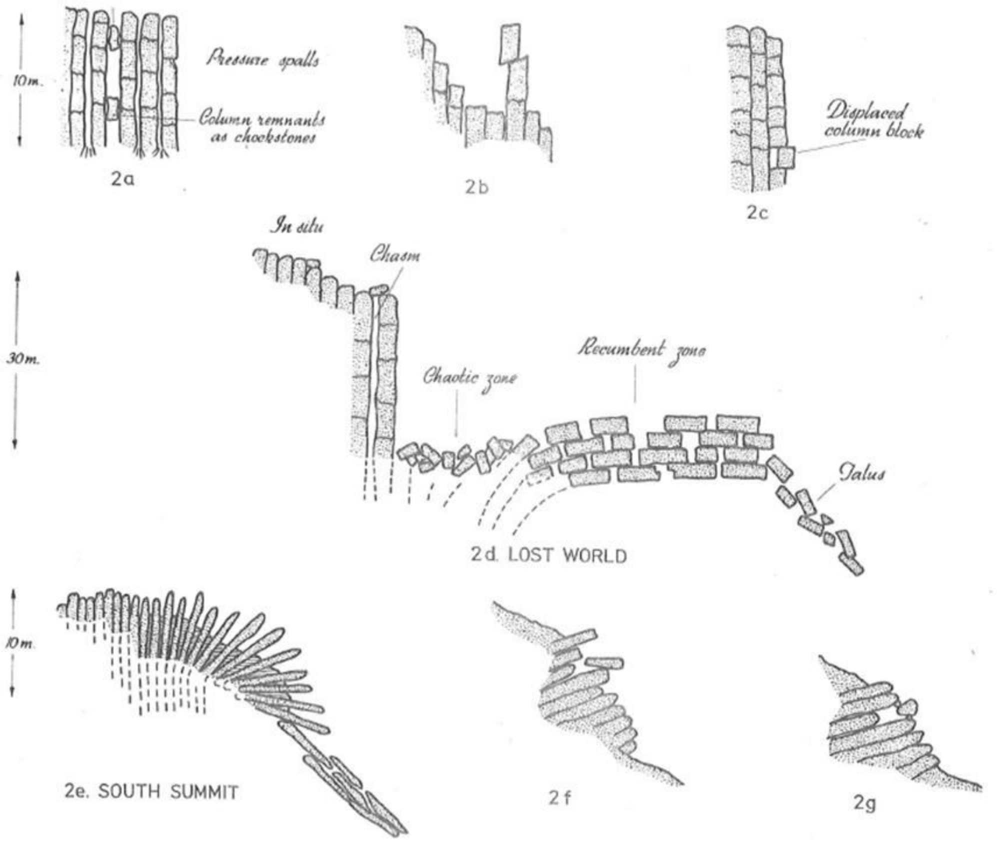

Figure 13 Examples of dolerite escarpment failures (from P.C. Stevenson 1980)

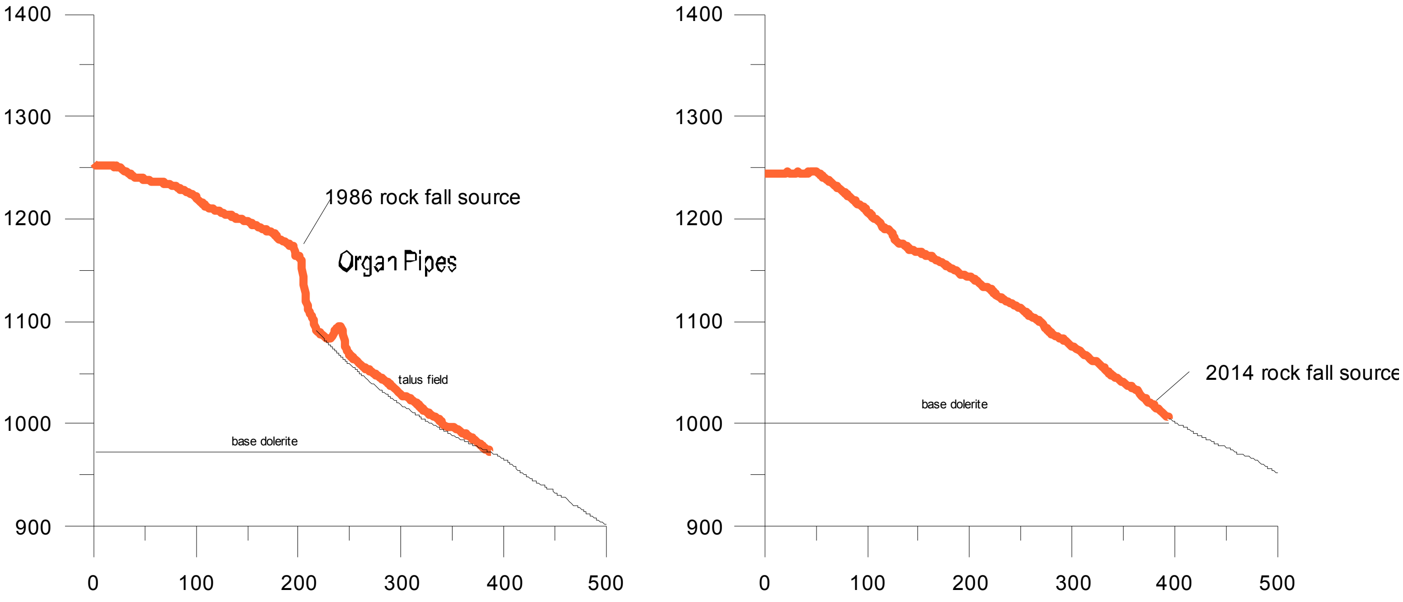

Figure 14 Comparison of slope profiles on the escarpment. Distances are in metres and no vertical exaggeration

Final Stop: Chalet

We have reached the end of the journey where we will meet the bus. However, before we leave from here we can see and comment on other features. Below the road, in contrast to what we have just seen, soils are developed within the slope deposits and the clasts themselves are in places highly weathered. This weathering process also applies to dolerite as observed in some places (e.g. Figure 15).

Note that perennial springs are present at the chalet indicating that the water table is now close to the surface and is passing through the slope deposits. Clays in this chemically-weathered material are dominated by halloysite and smectite, two very low strength clay mineral types. This weathering phenomenon has reduced the strength of the material to the point that it is susceptible to slope failure in our current climatic regime There is a recorded history of debris flows occurring on this mountain associated with extreme rain fall events and many features in the landscape (e.g. Figure 1) suggest that it is a widespread process. Debris flows can be extremely hazardous as evidenced by a 200 000 m^3 event in 1872 that travelled through a northern suburb of Hobart (Stevenson et al. 2016). We have mapped hundreds of these features in Southern Tasmania and in May of this year one initiated below the Lost World Topple as a result of an extreme rainfall event. The hazards posed by debris flows originating on the mountain is something that MRT is currently working on.

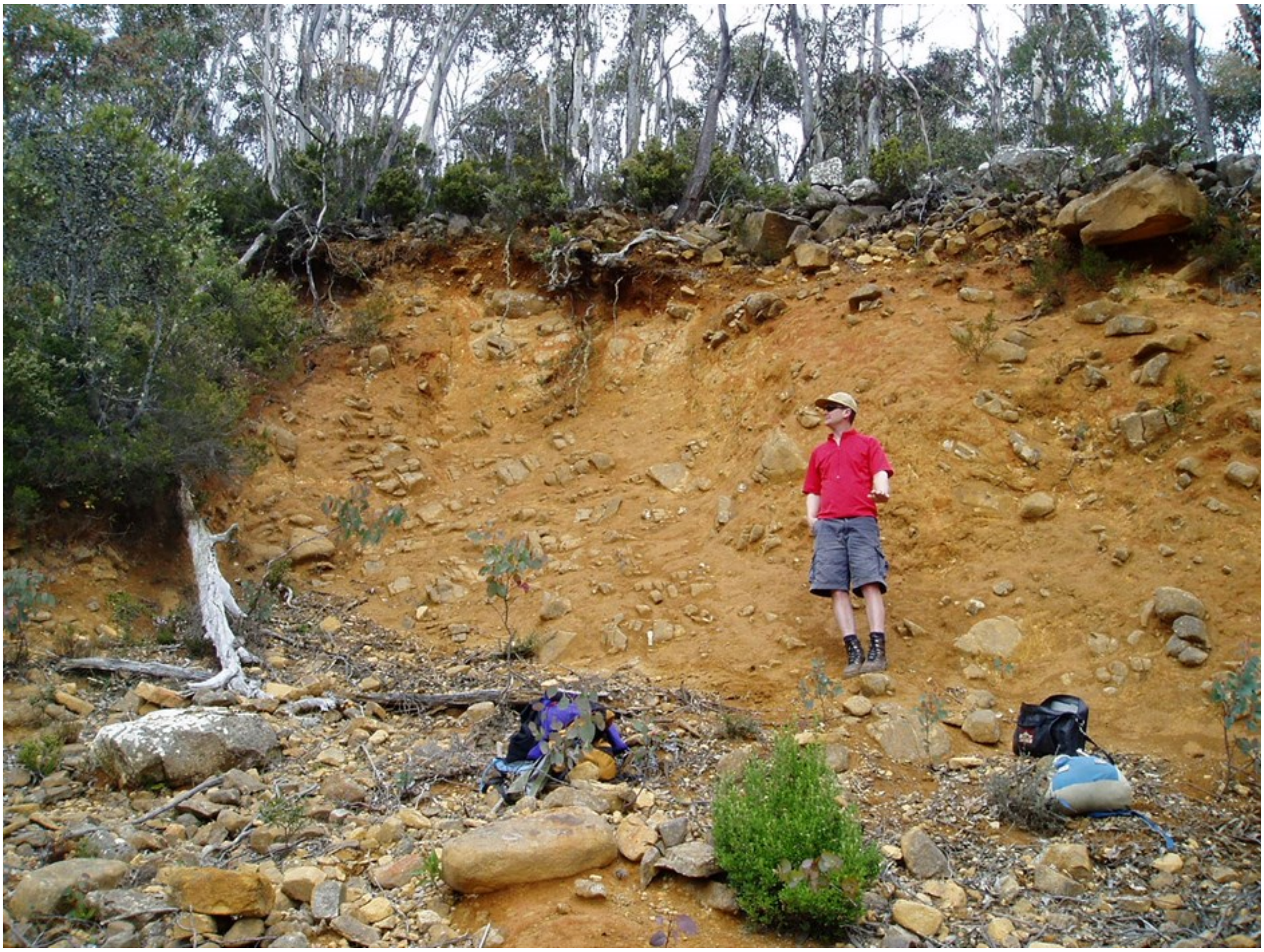

Figure 15 Example of extremely weathered dolerite capped by periglacial block fields, North side of Mount Arthur .

Escarpment retreat rates and rock fall likelihood

While you have been walking in the area where rock fall processes have clearly occurred you may have been pondering the chances of an event occurring today! Typically, these estimations are difficult to perform with any confidence but here I will provide a method to compare the observational record with geological constraints.

MRT maintains a publicly available landslide inventory within which a few events have been recorded. Unfortunately it does not pretend to be a comprehensive record and typically relies on external parties voluntarily providing information to us. Our landslide database has a record of three significant rock fall events in 32 years from the escarpment segment between the Organ Pipes and the Ice House Track 3.7 km to the South. In other words at least one significant event a decade (0.1 annualised probability).

The geological constraints centre on estimating the long term rate of retreat of the escarpment and how many typical failures (e.g. single column rock falls, column width 1.5 m) one could expect along in the same annualised manner as the observational record. In doing this calculation there are some important assumptions to declare. For instance, short term retreat rates will have varied depending on climatic regime over the geological period considered. Smaller rock fall events may be occurring much more often and an unknown component of the escarpment will be removed through other processes such as in solution – something that again is difficult to quantify.

Calculations of the retreat rates are provided in the table below for two time periods assuming that the escarpment formed as a result of fault movement 2 km away. This calculation indicates that a rock fall of dimensions 1.5 m diameter by 5 m length on the 300 m high 3.7 km escarpment may occur between 3 and 10 events per year.

If we accept the older initiation age the observational and the calculated methods are about one order of magnitude apart which, given the limitations and assumptions, are not too far apart. This approach could form the beginning of a risk assessment to visitors in the park.

Age of fault initiation	Distance of retreat	Long term rate of retreat	Annual probability of topple/rock fall event (5m x 1.5m dimensions) somewhere along 3.7km NNE escarpment (300 m high)
60Myr initiation	2km	33 m/Myr	3
20Myr initiation	2km	100 m/Myr	10

Table 1 Probability estimate of a single topple failure based on a number of geologically-focused assumptions

Concluding Remarks

This ends our field trip and I hope that you have enjoyed the mountain scenery and the exercise. I hope that you have also gained an insight into the mass wasting processes that occur in mountain environments and the methods for understanding the hazards these present.

References

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