LEEUWIN-NATURLISTE REGION GEOLOGY & LANDFORMS

ITS GEOLOGICAL HISTORY & GEOHERITAGE

Presented to:

- *Cape Naturaliste Conservation Enterprise; and*
- *Related Friends*

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29th January 2025

This is a generic talk about the regional geology. I do not focus on many specific site details but can respond to specific questions

THE TALK CONTENTS

1. Geological introduction
2. Geological setting
3. The Perth Basin evolution and plate tectonics
4. Bunbury Basalt & our local volcanoes
5. Geology of the Leeuwin Complex
6. Sand dunes – Tamala Formation
7. Laterites
8. Questions

FIRST – GENERAL COMMENTS:

Geology is one of two fundamental environmental sciences; the other is climate
Both are inextricably linked to their history

All other environmental attributes in the natural world depend on these two:

- All living animals depend on plants (or other animals).
- Plants depend on the soils and the water in soils.
- The soils and water depend on the rocks and the rainfall and what has happened to those things through geological time.

SECOND – GEOLOGICAL DIMENSIONS:

We all use drawings, plans and maps – two dimensions

Geologists need to work on the rocks below the mapped surface – three dimensions

And we must determine when they came to be – the fourth dimension of time

- How old am I? Do we think a lot of time has passed since our birth?
- How about the 2000 years since time of Christ when our calendars started?
- Geologists deal in millions of year. Hundreds of millions. And thousands of millions of years

Do we appreciate their length? **NO ONE CAN TRULY APPRECIATE THE ENORMITY OF GEOLGICAL TIME!**

The setting

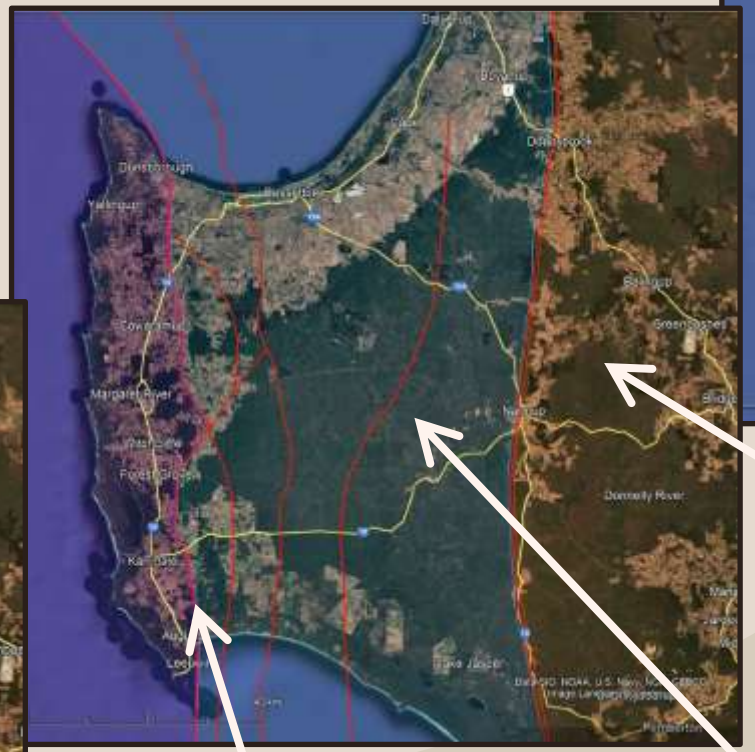
Google Earth – satellite view

Three major tectonic units – few rocks

Many faults not shown

On top of the rocks:

Sand dunes and more sand dunes and a laterite profile



Yilgarn Craton >2.6Ga

Perth Basin 300-0Ma

Leeuwin Complex 1000-500Ma

Ma = mega-annum; Ga = giga-annum

More detail near Cape Naturaliste

Quindalup dune – limesand
See samples in jars

Spearwood dune – limestone under sand

Bassendean dune – quartz sand, lime dissolved

Yoganup paleoshorline sand along the base of the Whicher Scarp – quartz sand

All dunes are less than 2 million years ago (Ma)

Yallingup

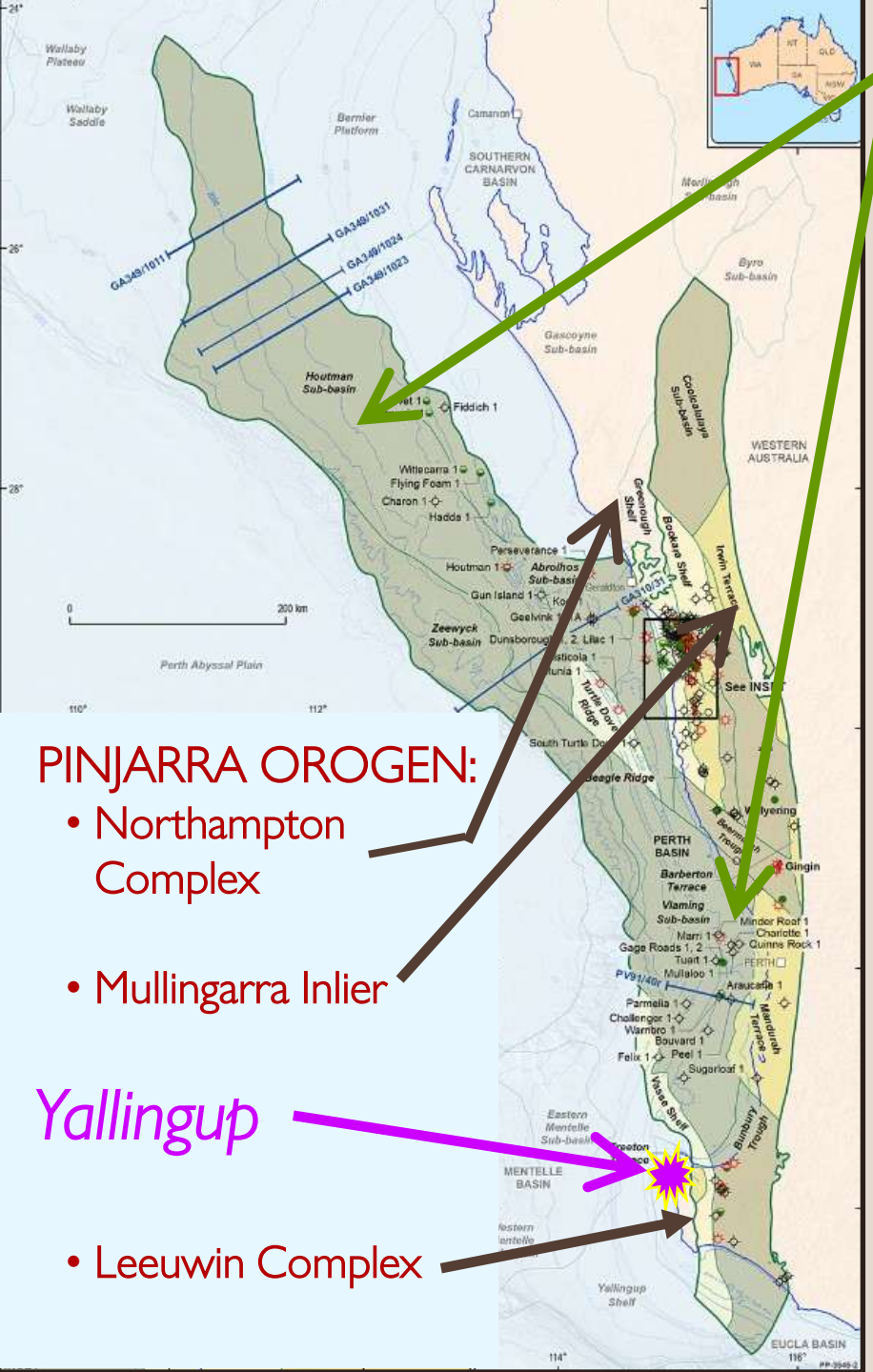
Dunsborough Fault

Laterite profile, soil over rock

Blackwood "Plateau" or "Sunkland" – laterite profile over sediments. Note agriculture on better soils are

Perth Basin - the big picture

- Sandwiched between Yilgarn and India
- Shallow-marine and terrestrial sediments
- Deposited between about 300 and 100 Ma
- 1300 km long, 220 km wide
- A gulf, open to Tethyan Ocean to the top, land-locked in the south
- The coast migrated north to south and back periodically



Beneath the Perth Basin is the Pinjarra Orogen

It pokes above the sediments in a few places

* **Leeuwin Complex** (beneath us)
* Mullingarra Complex
* Northampton Complex

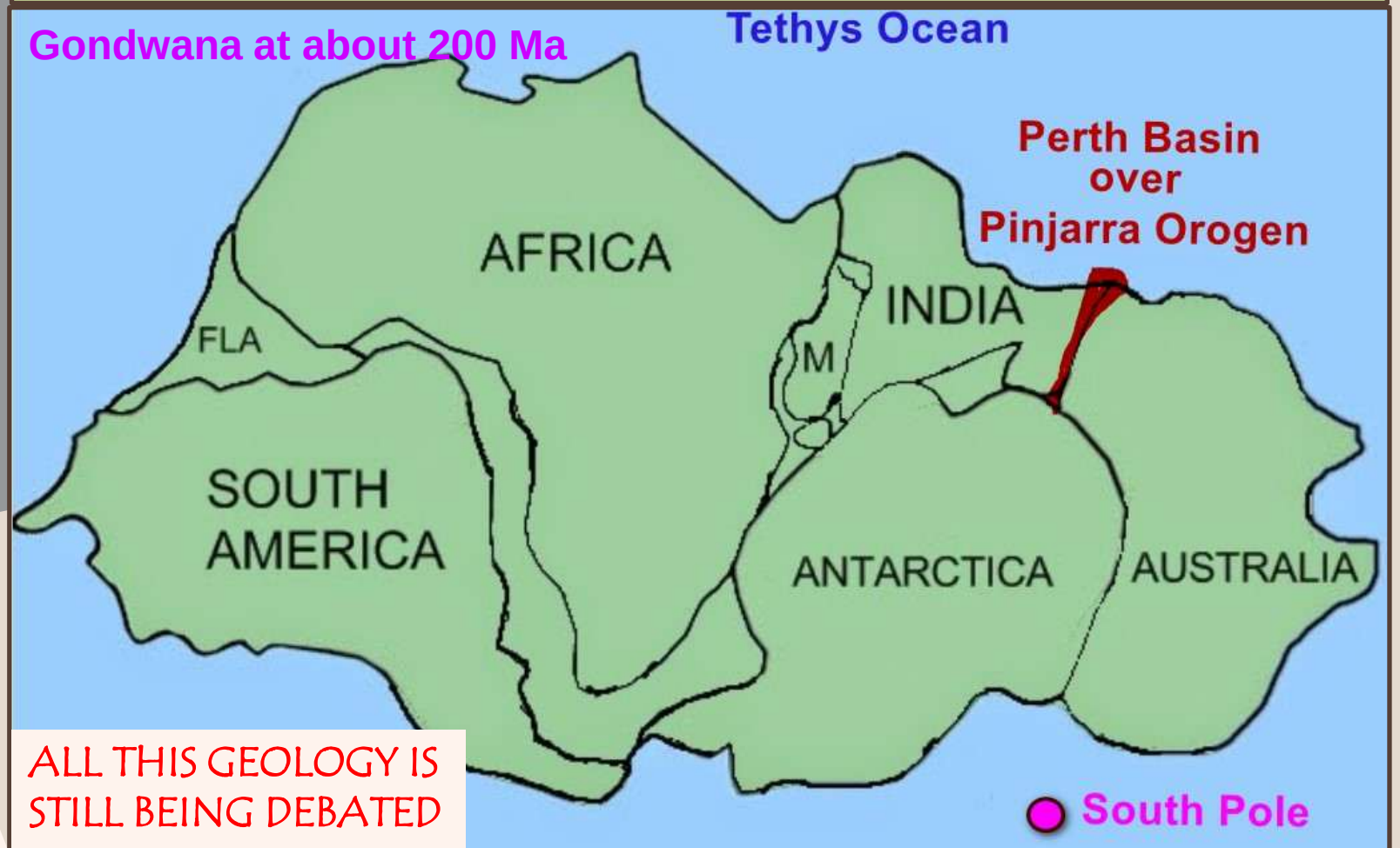
Crystalline rocks, igneous and metamorphic

PLATE TECTONICS (CONTINENTAL DRIFT)

Continental plates are 20 to 40 km thick and float on mantle rock that is semi-rigid, has higher density and is in motion

- Offshore from WA is Greater India – northern extension of the subcontinent
- Between WA and India was a gulf open to ocean to north and land-locked to the south
- Sediment carried by rivers off south coast of WA and Antarctica - the gulf kept filled up – coast moved "north" as sediment flowed in and "north" as the Pinjarra Orogen slowly sank
- Up to 15,000 metres of sediment accumulated (3km just E of fault)
- It accumulated at the rate of a millimetre per decade on average

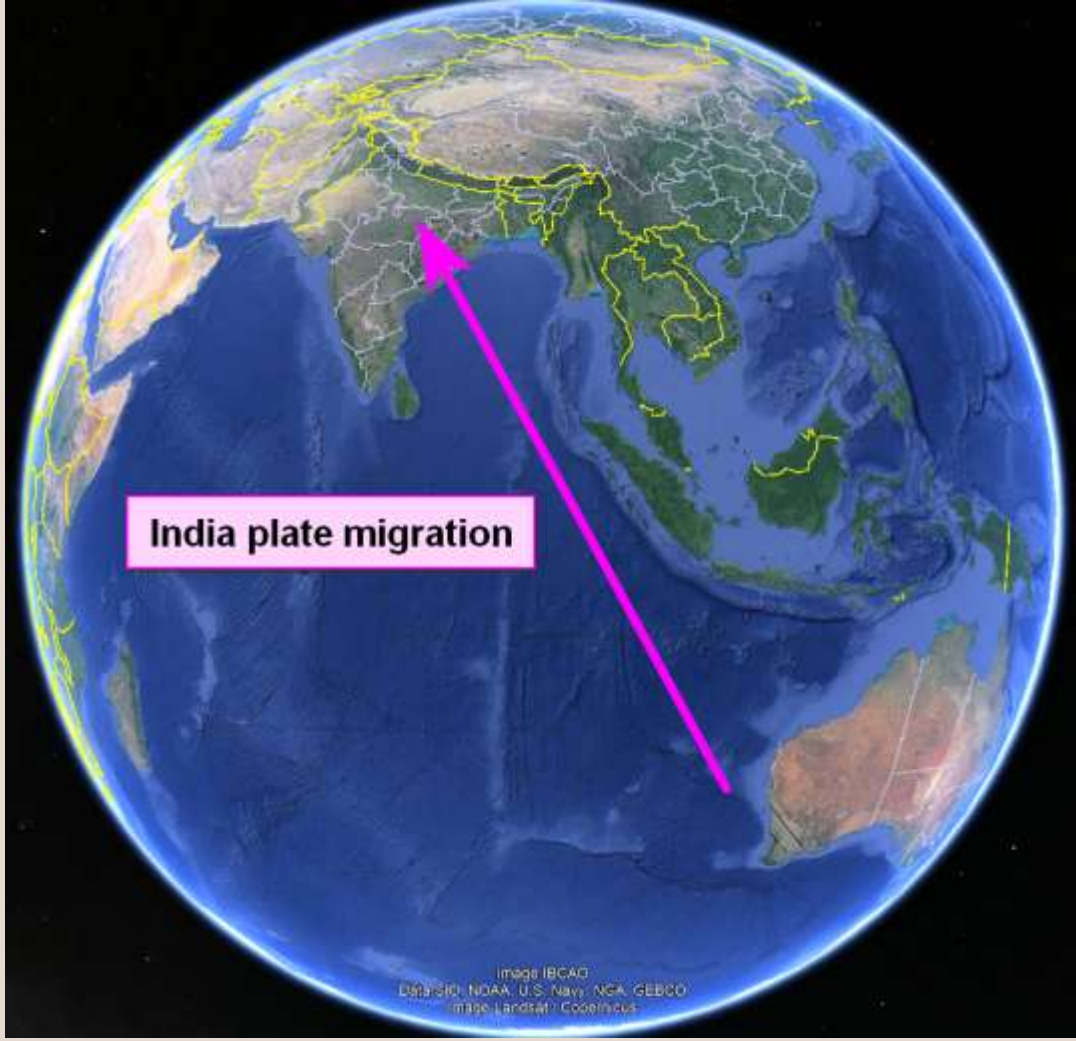
- Map of Gondwana about 200 million years ago (Ma)
- At about 190Ma South America, Africa, Madagascar and Florida separated as West Gondwana
- Leaving East Gondwana – Australia, India and Antarctica



ALL THIS GEOLOGY IS STILL BEING DEBATED

What happened to India?

- 132 million years ago, India separated from East Gondwana
- It migrated northwards, initially at 20 cm per year – a breakneck speed
- 30 million years ago the north hit Asia and buried itself under the Asian continental plate
- Tibet plateau at an altitude of over 4000 metres consists of two continental plates, one over the other and so the top is high as the plate is double thickness
- Himalayas pushed up

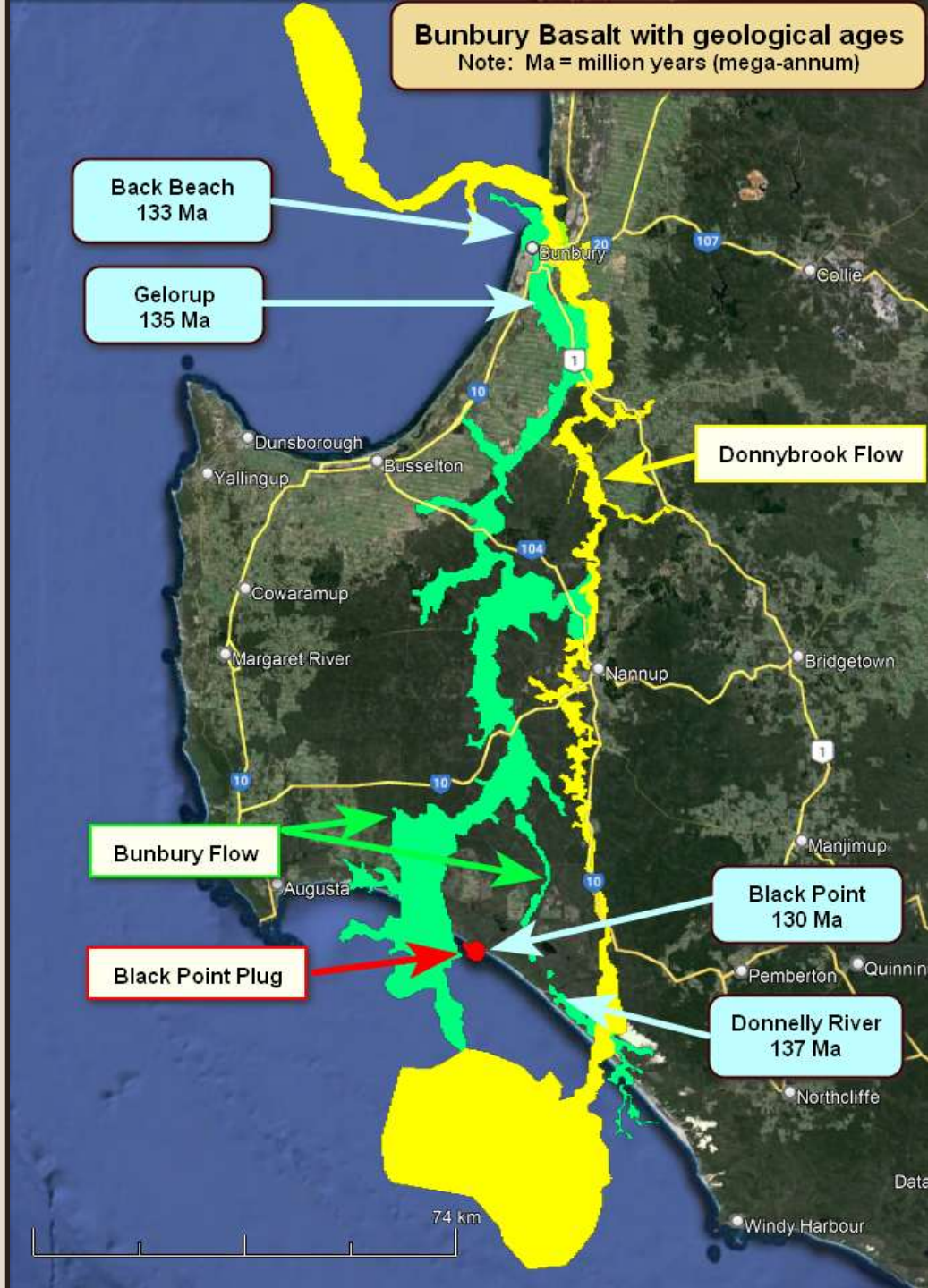


Note that Indonesia did not exist at that time.

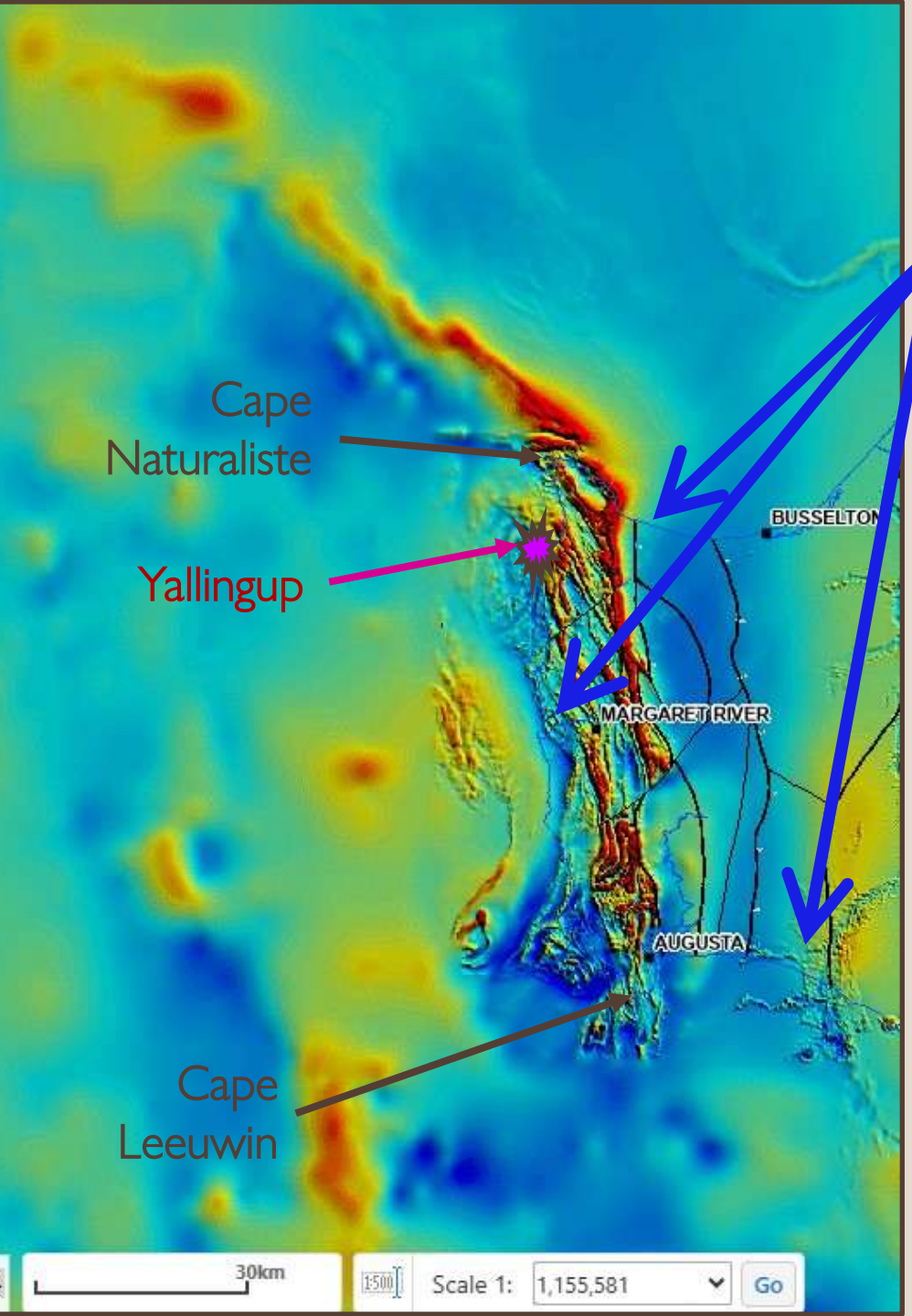
ALL THIS GEOLOGY IS STILL BEING DEBATED

BUNBURY BASALT

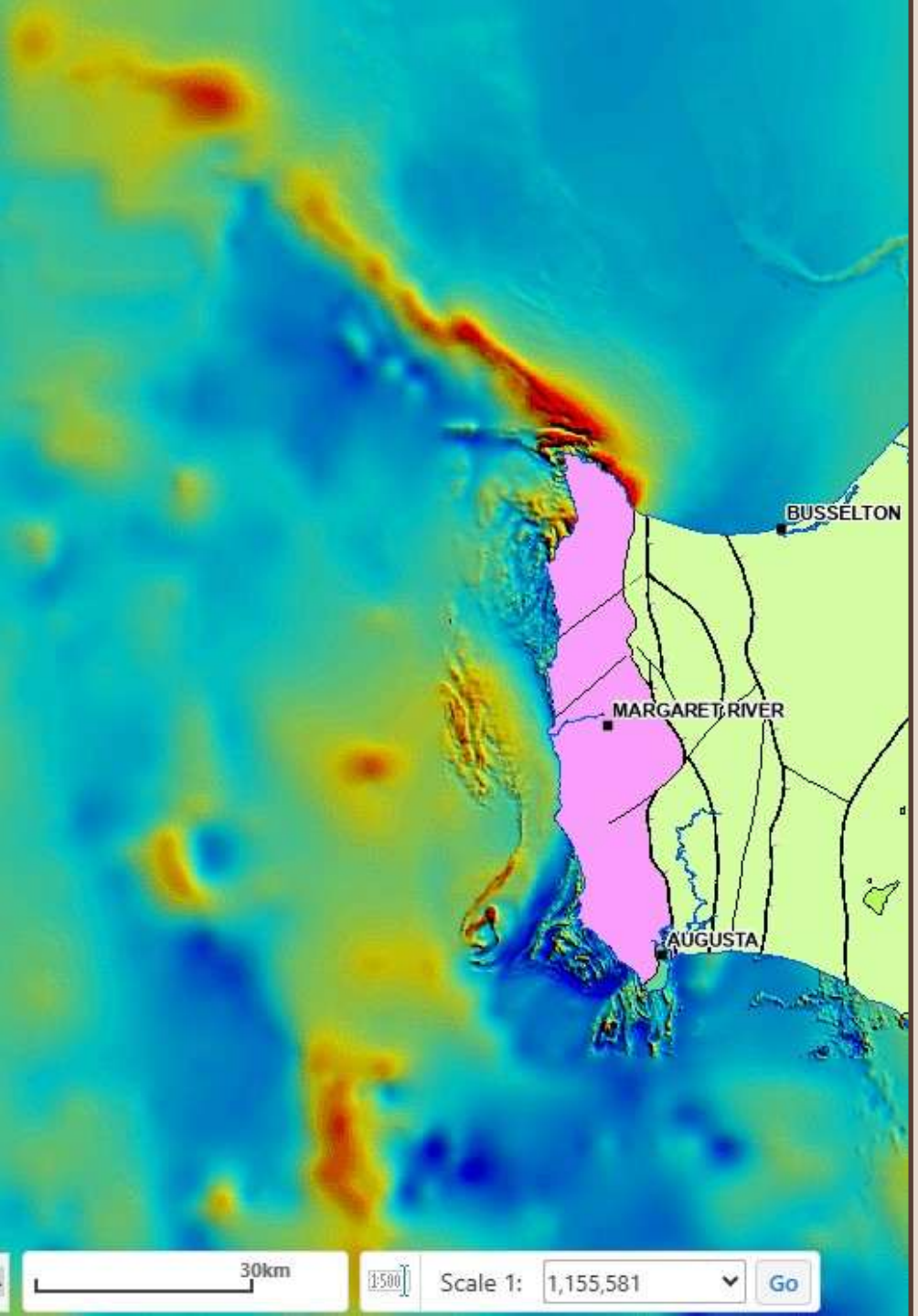
- As the forces that split off India started, the crust started splitting
- Magma from the mantle rose along some cracks to form volcanoes
- The lava flowed down valleys to the north
- First was a valley between 137 and 133Ma - the green **Bunbury Flow**
- A second valley lava – the yellow **Donnybrook Flow** - followed a new valley
- Finally at the red Black Point a circular lava dated at 130Ma
- The vents (volcanoes) have yet to be found. Pattern implies a number of vents
- Longest valley lava flows on Earth?



Leeuwin-Naturaliste Ridge



- First some geo-magic – aeromagnetic image
- Focus on faint blue coastline
- Details of the Earth's magnetic signature with variations caused by the rocks. Made by flying a recording magnetometer at low altitude
- Black lines are faults



Leeuwin-Naturaliste Ridge

Now we add geology on land

- Yellow is Perth Basin
- Pink is Leeuwin Complex
- Mostly under laterite profile or sand dunes
- Complex extends 100km to northwest and at least 25km to south

REGIONAL GEOLOGICAL MAPPING

Limited outcrops, mostly concealed

Curiously Perth Basin sediments (Leederville Formation) lap 4km onto eastern Leeuwin Complex

This means the top of the Leeuwin Complex was near or below sea level at about 100Ma

GENESIS OF LEEUWIN COMPLEX

- Mawson Plate (including Antarctica) had collided with Yilgarn Craton along south coast of WA at about 1200Ma lea forming supercontinent Rodinia. This split apart at 9

- Then the supercontinent Pangea assembled at about 750Ma consisting of all continents
- Then about 350Ma Pangea split forming Gondwana and Laurasia
- India collided with WA but timing is debateable
- Some metamorphism of Leeuwin Complex is dated at 1090 – 1020Ma
- Need more research to work out what that means
- We have yet to determine if the Pinjarra Orogen was part of WA, part of India or something else.
- Dates of rock give mixed interpretations

PANGEA

ALL THIS GEOLOGY IS STILL BEING DEBATED

ROCKS OF LEEUWIN RIDGE

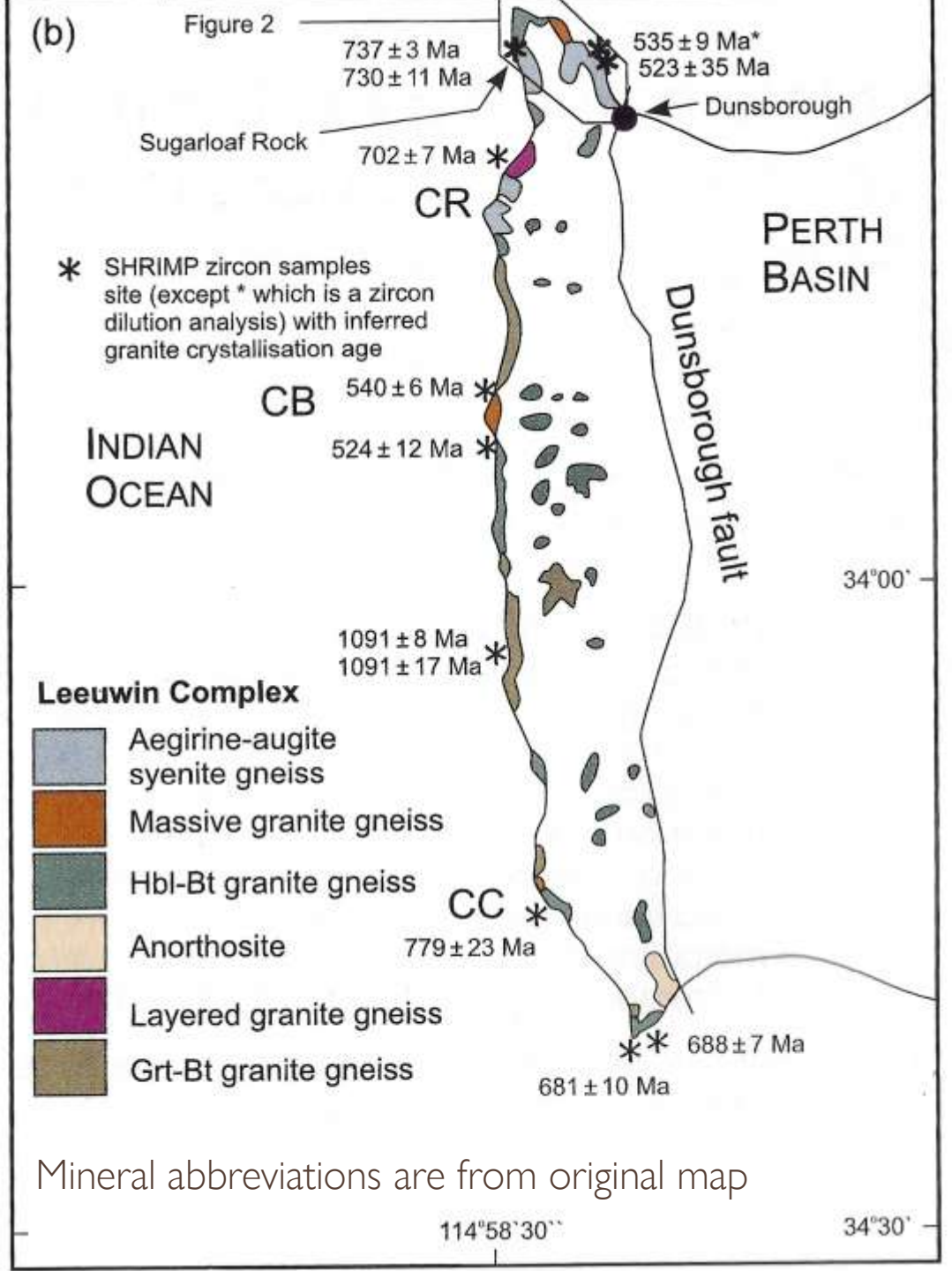
Nine discrete types, seven in Leeuwin Complex and two overlying it

Note the rock types and ages in the Complex:

- ~1090Ma near Conto
- ~780Ma Cosy Corner
- ~700-730Ma Sugarloaf and Yallingup
- ~680Ma near Cape Leeuwin
- ~520-540Ma Meelup and Gracetown

Modelling of the chemical signatures implies most started as granite derived from melting of sedimentary rocks – giving different types of granite depending on the parent

They were metamorphosed through deep burial at temperatures of up to 900C and at pressures of 1 gigapascal



GEOLOGICAL TEMPERATURE AND PRESSURE

Both increase with depth

- TEMPERATURE – we refer to the geothermal gradient – the general rate is 30C per km of depth (but varies)
- PRESSURE - GPa – a thousand million pascals (gigapascals). You may have noticed the Bureau of Meteorology quotes air pressure in hectopascals (100 pascals or hPa) so 1GPa is 10 million times we experience - 10,000,000 times atmospheric pressure. So, these rocks were highly stressed
- Hence these rocks were taken to a depth of some 30 km
- In those conditions parts started melting and produced pegmatite veins as here
- They were subjected to directed stress that started to form layering or banding as mineral grains recrystalised and grew

THE ROCK

MOSTLY GRANITIC GNEISS:

- **Felspar**
- **Quartz**
- **Mica and other iron-bearing minerals**

Mineral layering emphasised by weathering of the gneiss

Mineral layering in the fresher rock can be subtle. Note the iron staining is a weathering product

More mineral layering in the fresher rock with a pegmatite vein through partial melting

THE ROCK - again

Two different rocks at Sugarloaf:

Pink granitic gneiss

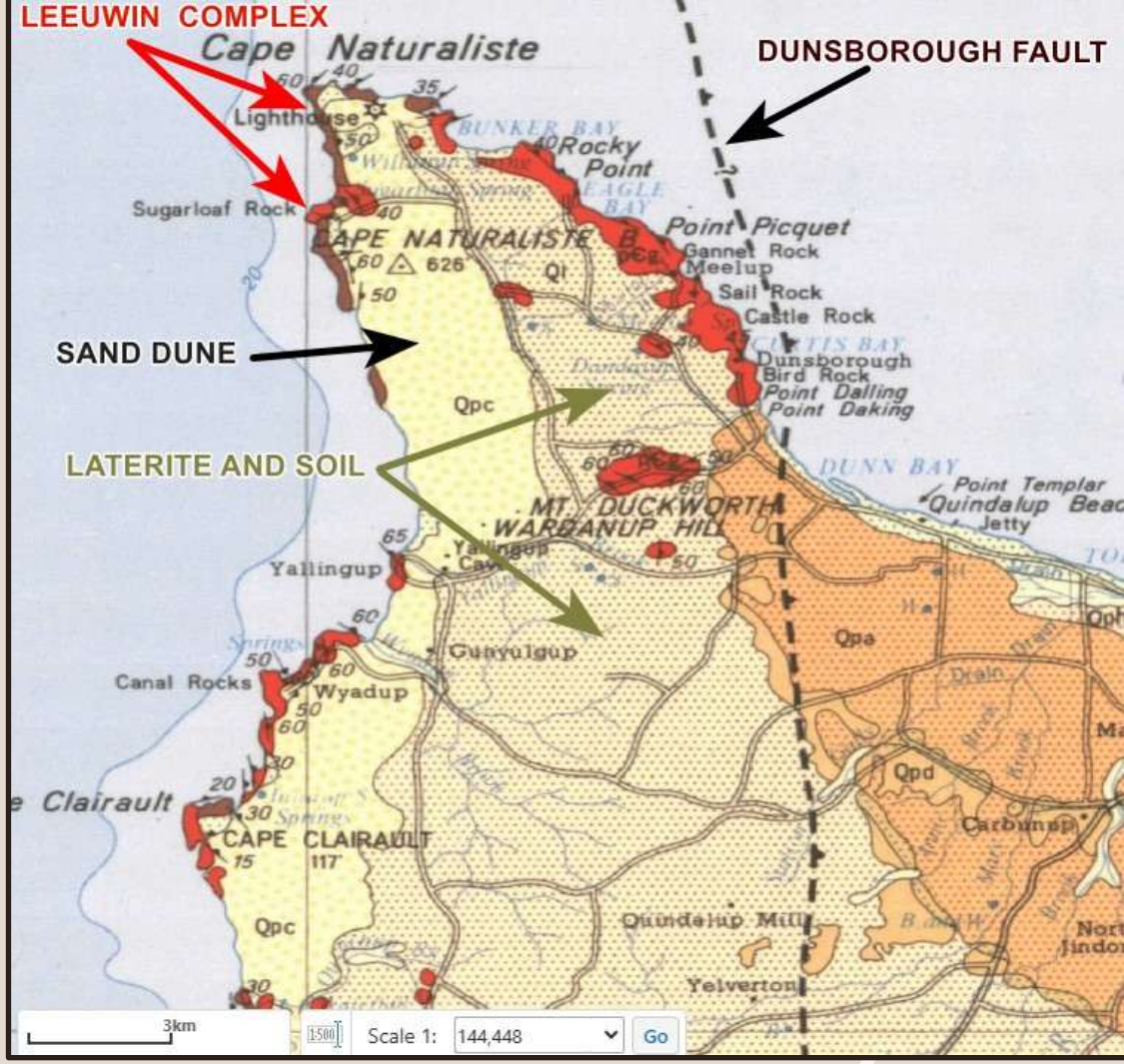
Grey granodioritic gneiss

Banded gneiss. Iron stained. Joints and fractures are picked out to

Amphibolite – black iron-rich minerals. Note M-fold!

Next story - the overlying sand

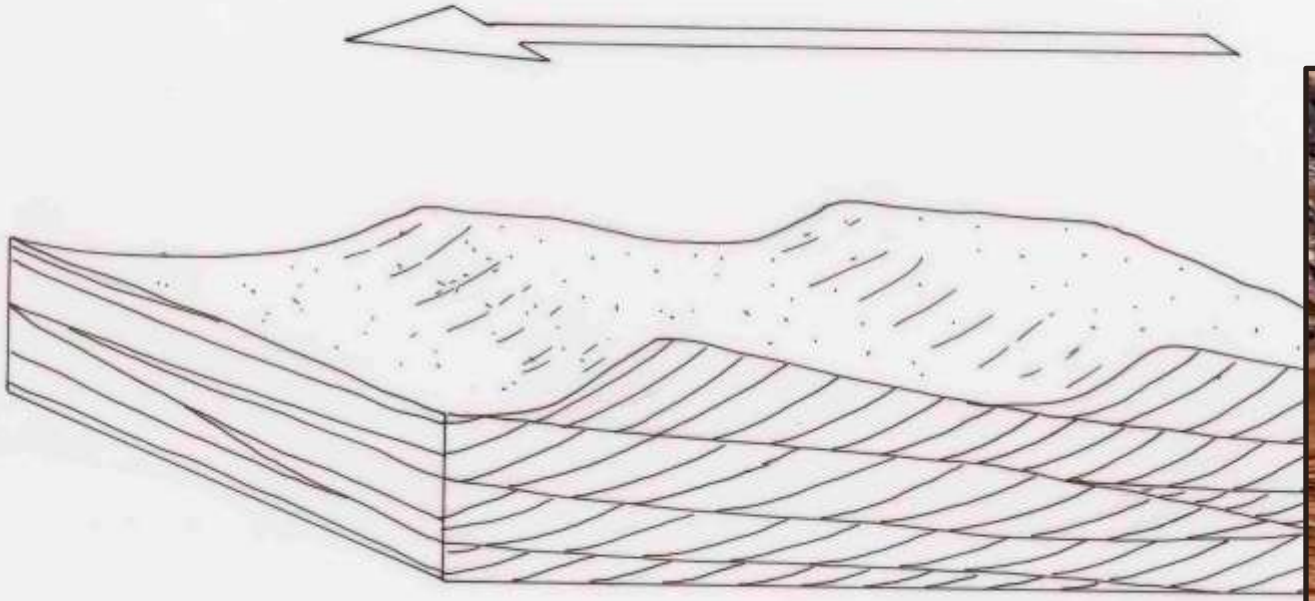
- Dunes up to 200m high
- Formed from limesand from breakdown of seashells in last 2Ma or less
- Limesand is rapidly cemented through rain water action to form limestone



Sand dune bedding

Sand blows up windward side of dune and drops on leeward side. Bedding slopes down. As winds change slopes change

A simple illustration
And a wind change may erode already-deposited sand



Dunes are more complex in nature

Soils form on sand - **paleosol**

- When dunes stop blowing, vegetation grows
- With carbonic acid from roots, decay increases dissolving and precipitation of lime
- Soil limestone becomes hardened
- Fossil soil horizons are termed **paleosols**
- Below ground, the limestone can dissolve forming caves
- Meekadarrabee Tufa Barrier (upstream from Ellensbrook heritage homestead) shows where the lime dissolved by cave formation is precipitating – on State Geoheritage Register

Paleosols and rhizomorphs

Sugarloaf rhizomorphs – "*rhizo*" pertaining to root; "morph" pertaining to morphology or shape

Hamelin Bay registered on the State Geoheritage list– five stacked paleosols
Top surface damaged by revegetation action

Lime in groundwater is very mobile geologically

Beach rock (gneiss cobbles) cemented with limestone

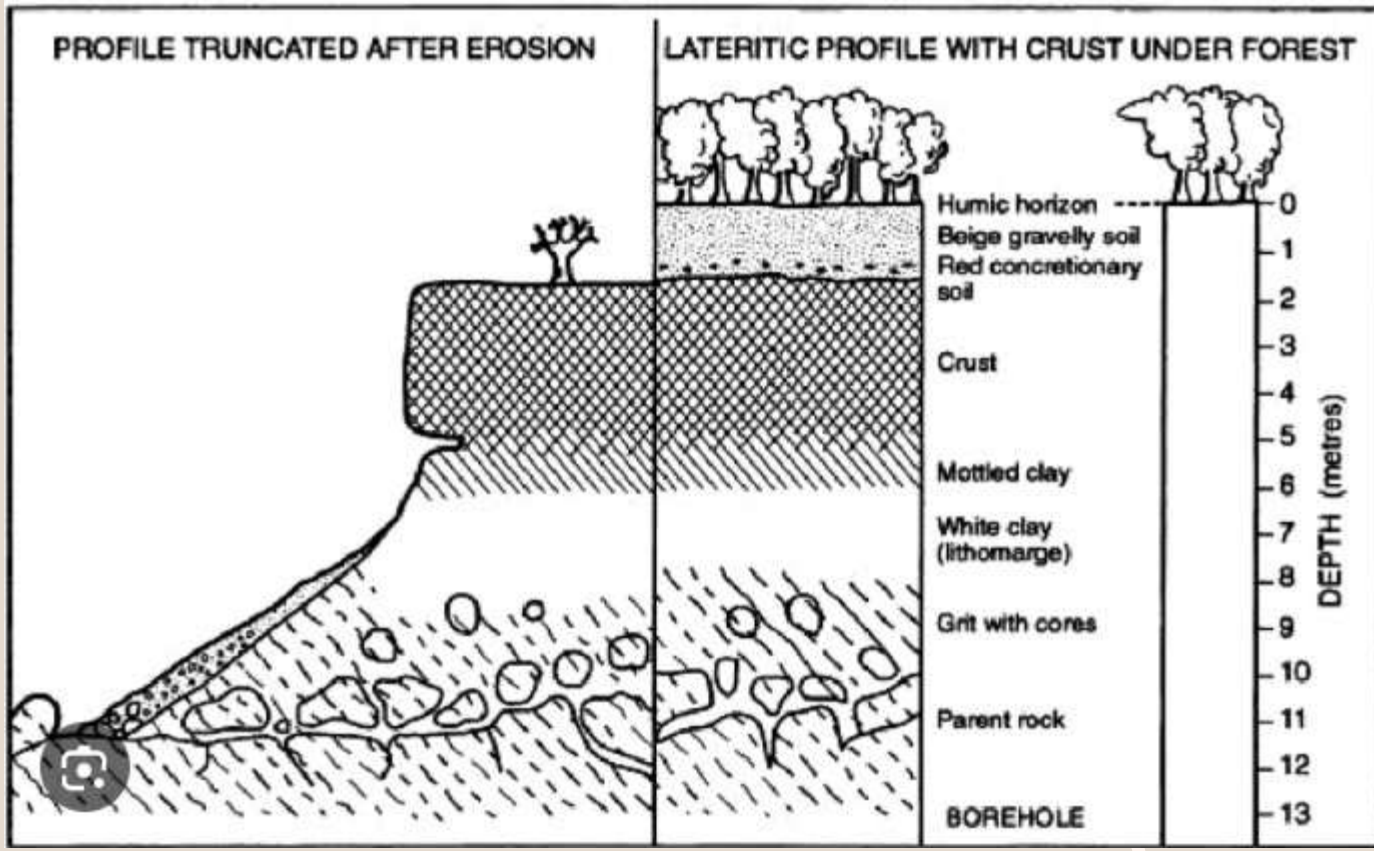
Massive limestone

Laterite profile

Commonly misused and not understood Terminology:

Laterite	Ferricrete
Coffee rock	Caprock
Ironstone gravel	Ironstone etc

- **Five zones** in profile – theoretical profile often not seen
- Formed in humid climates
- Caprock or Lateritic caprock is hard, resists erosion, protects softer underlying material



DARLING RANGE MAP

Laterite profile – EXAMPLES OF ZONES

Upper part of laterite profile.

- Resistant ferricrete - caps and holds up the slope
- Mottled zone missing
- Bleached – clay-rich –zone
- Note tumbled blocks
- Typical breakaway country in the outback

Example of mottled zone – iron-rich (ferruginous) patches with bleaches

WHAT THE TALK COVERED

Geological intro

Geological setting

The Perth Basin and plate tectonics

Bunbury Basalt & our local volcanoes

Leeuwin Complex – geology and the complexity of its formation

Sand dunes and caves – Tamala Formation

Laterites

Questions

THE END

Thanks for your interest

ACKNOWLEDGEMENTS

To Geological Survey of WA colleagues and other geologists, a number of whom helped with understanding the geological background and using GeoVIEW, the GSWA's geological website

Several Curtin University geologists, especially scientific papers they authored

Other colleagues

Many illustrations are based on Google Earth images or images from the Internet and they are acknowledged

Several papers from Australian Journal of geology were illustration sources