Pacific atoll enigmatic 'conglomerate platform' deposited by tsunami during Holocene higher sea level: supportive data from Fakarava, French Polynesia

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For all cited references, see Slide 39

Google Earth

Abstract

On Pacific atoll rims, sandy islets perch on a Holocene-coral-rubble 'conglomerate platform' (CP) ~1.5 metres (m) thick. The CP often protrudes oceanward as a bare rock ledge, its top emergent at high tide, the distal scarp eroding by storm waves, and its surfaces darkened by algal boring. Below and oceanward of the CP is the reef-flat. My 2018-19 observations on Majuro and Tarawa atolls necessitated reinterpreting CP coral debris as ejected *outward*, from the lagoon (not inward from the forereef), by bilateral vortices induced by a tsunami passing overhead when no islets existed and sea level (SL) was ~2m higher than now, during Fairbridge's (1961) Abrolhos highstand (Higgs 2022 GSA abstract 10.1130/abs/2022am-377547). This model is reinforced by my 2023 studies of Fakarava and nearby atolls, where aerial images again show many CP bodies with a "tulip"-shape (Higgs 2022), a long (100s m) "stem" terminating in an *oceanward*-flaring "flower" (e.g. Google Earth at 16°23'14"S 145°40'37"W). Stems can again show "nested crescents" (e.g. SW Fakarava, 16°26'24"S 145°37'23"W); visiting one example I found oblique, near-symmetrical, round-crested bedforms (spacing ~1m, height at least 20cm; antidunes?) of coral-pebble conglomerate, poorly exposed (crests only) between remnants of bouldery CP cover up to ~1m thick. Other CPs on aerial images are simple fans, splaying from their apices at the lagoon edge and ending 10s m short of the ocean. These fans can merge laterally, forming a composite CP, straddled by an islet much longer (km-10s km) than wide (200-500m), like NE Fakarava, where the CP protrudes up to ~80m oceanward, its scalloped front (Google Earth) reflecting fan mergence. Examined at Teariki, this CP is bouldery rubble, patchily removed by erosion except for a distal fringe up to 15m wide and ~1m thick (prolonged sea-water contact slows cement dissolution by rain?). This fringe is a set of *oceanward*-dipping foresets (cf. Ebon, Majuro, Tarawa atolls; Curray et al. 1970; Newell & Bloom 1970; Higgs 2022) with shore-parallel strike (e.g. 16°07'59"S/145°35'55"W). Inboard of the fringe, erosional windows in the CP expose benthic-foram-rich grainstone of the reef-flat; usually <10cm are visible, with up to 40cm more in trough-like 'sags' ~3m wide (concave-up base), >50m long, and kinked. Sags suggest subsurface karstic-void growth, requiring a nearby rain-catchment (islet).

40" (not 55)

Geological Society of America Abstracts with Programs. Vol. 56, No. 5, 2024
doi: 10.1130/abs/2024AM-402653

40 slides! In my talk I will focus on about 15.

Relevance of this study

(amplified in Slides 36-38)

1. Contradicts IPCC's belief that no sea-level (SL) oscillation in the last 3ky exceeded 0.5m

2. Supports global Holocene 'Fairbridge Curve', with rapid meter-scale SL rises & falls (Fairbridge 1961, fig. 15), *unrelated to atmospheric CO2*

3. Supports Schofield (1977a) oscillating SL curve for Pacific atolls, with rapid meter-scale SL rises & falls

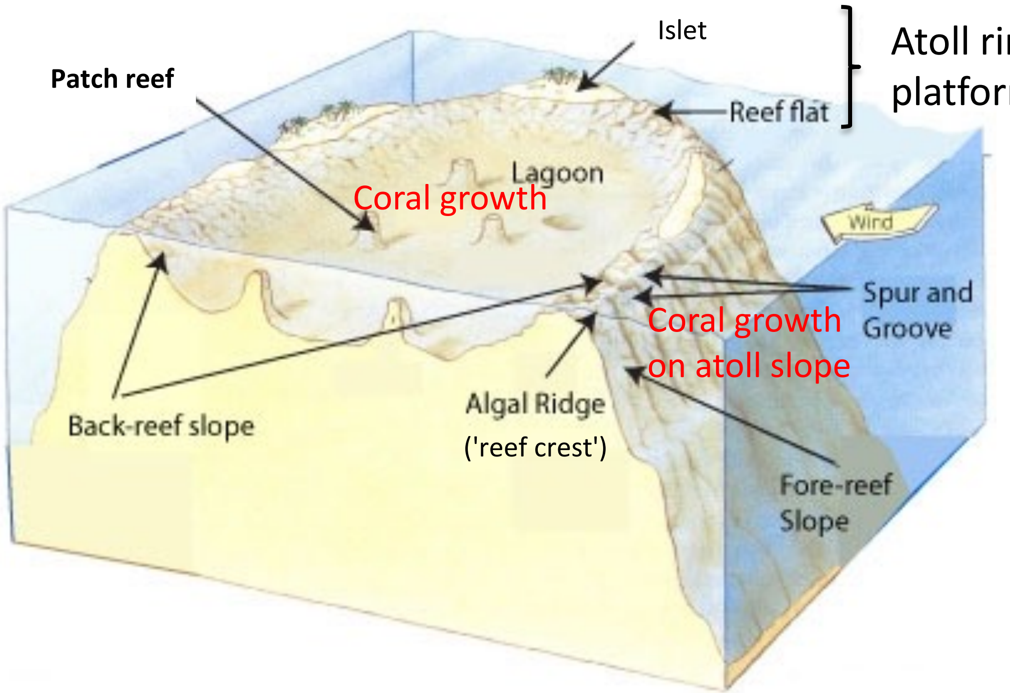
4. Supports previous authors' conclusion that subaerial (i.e. habitable) atoll islets only *exist* thanks to c.1-2m of Holocene SL fall

5. Supports reality of Fairbridge's subsequent 'Rottnest Submergence', shown by archaeological evidence to have totaled c.4m in only c.70y (c.430-500AD), correlating with an exceptional Arctic warm-spike (probably solar-induced), portending an imminent multi-meter SL rise due to 21st Century *man-made* Arctic warming

Location of atolls mentioned in abstract (also Mururoa)

https://www.nationsonline.org/oneworld/map/oceania_map.htm

Typical atoll



Atoll rim (omits conglomerate platform; see next slide)

https://sites.google.com/a/markham.edu.pe/mr-carter-s-igcse-geography/oceans/coral-reefs

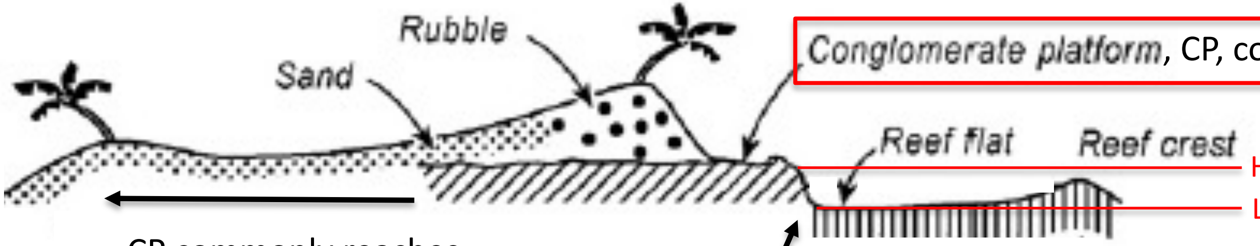
Atoll-rim 'conglomerate platform' (CP)

Idealised atoll rim
(Woodroffe 2008)

Sandy islet, perched on CP

Conglomerate platform, CP, coral rubble, up to boulder-size

Lagoon



High spring tide

Low

Ocean

CP commonly reaches behind islet
(Slides 15, 16, 21, 28)

Fakarava spring-tide range c.0.7m

CP edge never reaches atoll rim's oceanward edge


Conglomerate platform
Reef flat
Ocean
30
Teariki Lodge, 2023

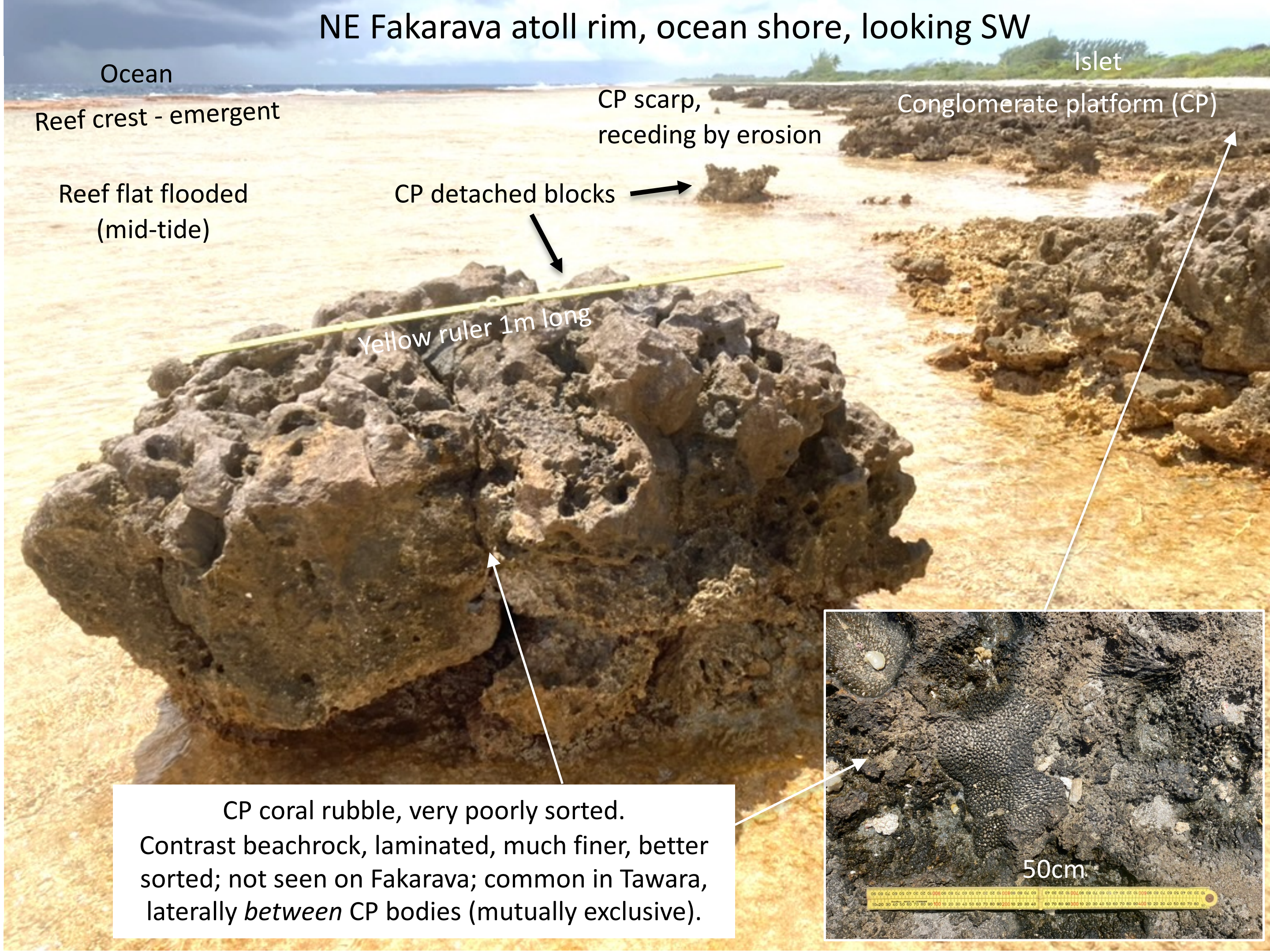
Conglomerate platform (CP): close-up character

1) Bordered by an eroding scarp. Erosion by hurricane waves? ... **& tsunamis?**

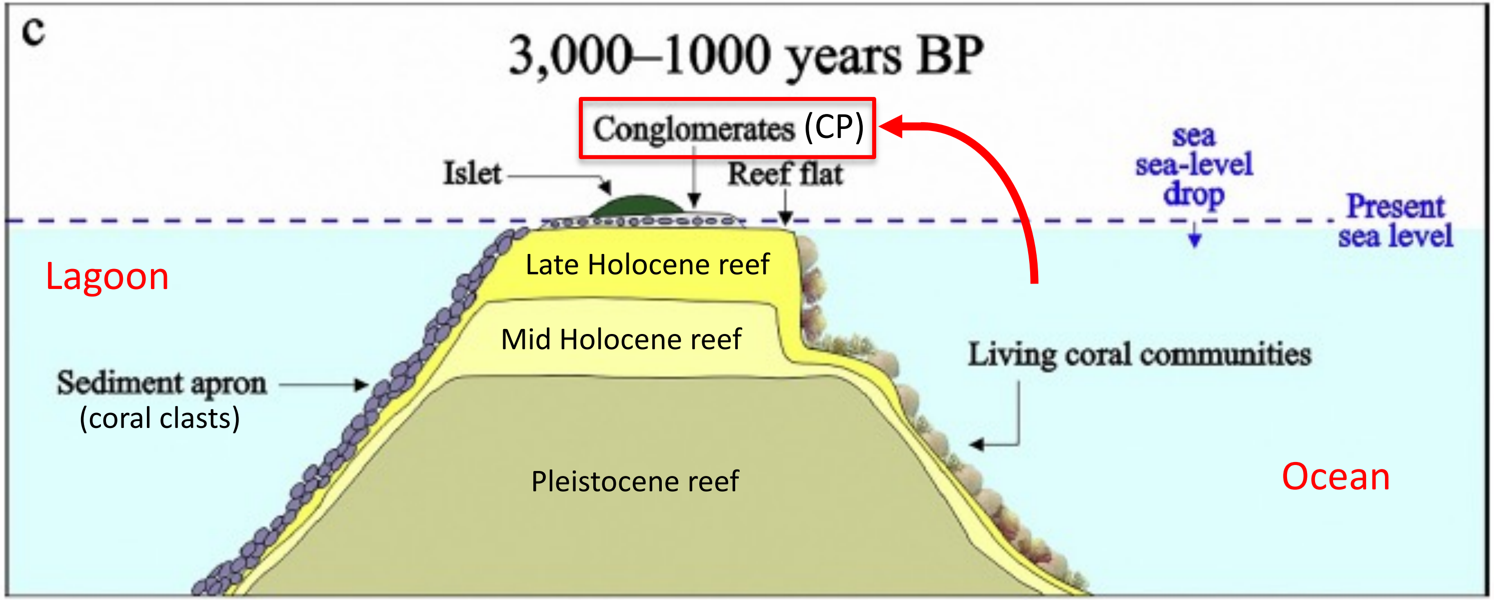
2) Surface blackened by algal boring (Littler & Littler 2013); white inside

Scarp proves CP is out of equilibrium in present intertidal setting

Suggests subtidal deposition at higher sea level (SL) & later emergence by SL fall



Conglomerate platform (CP) previously interpreted as storm deposits derived from atoll *front* ...



Montaggioni et al. 2021 p. 11 & fig. 12 ...

CP rubble deposited mainly 3ky to 1kyBP, while SL fell c.1m to its present level

Coral rubble (from living and dead coral on atoll front) was transported *lagoonward* incrementally by storms

See also Montaggioni et al. 2023

Aerial views (next 3 slides) reveal ...

- Conglomerate platform (CP) is 'patchy' (not pervasive)

- Two kinds of CP body ...

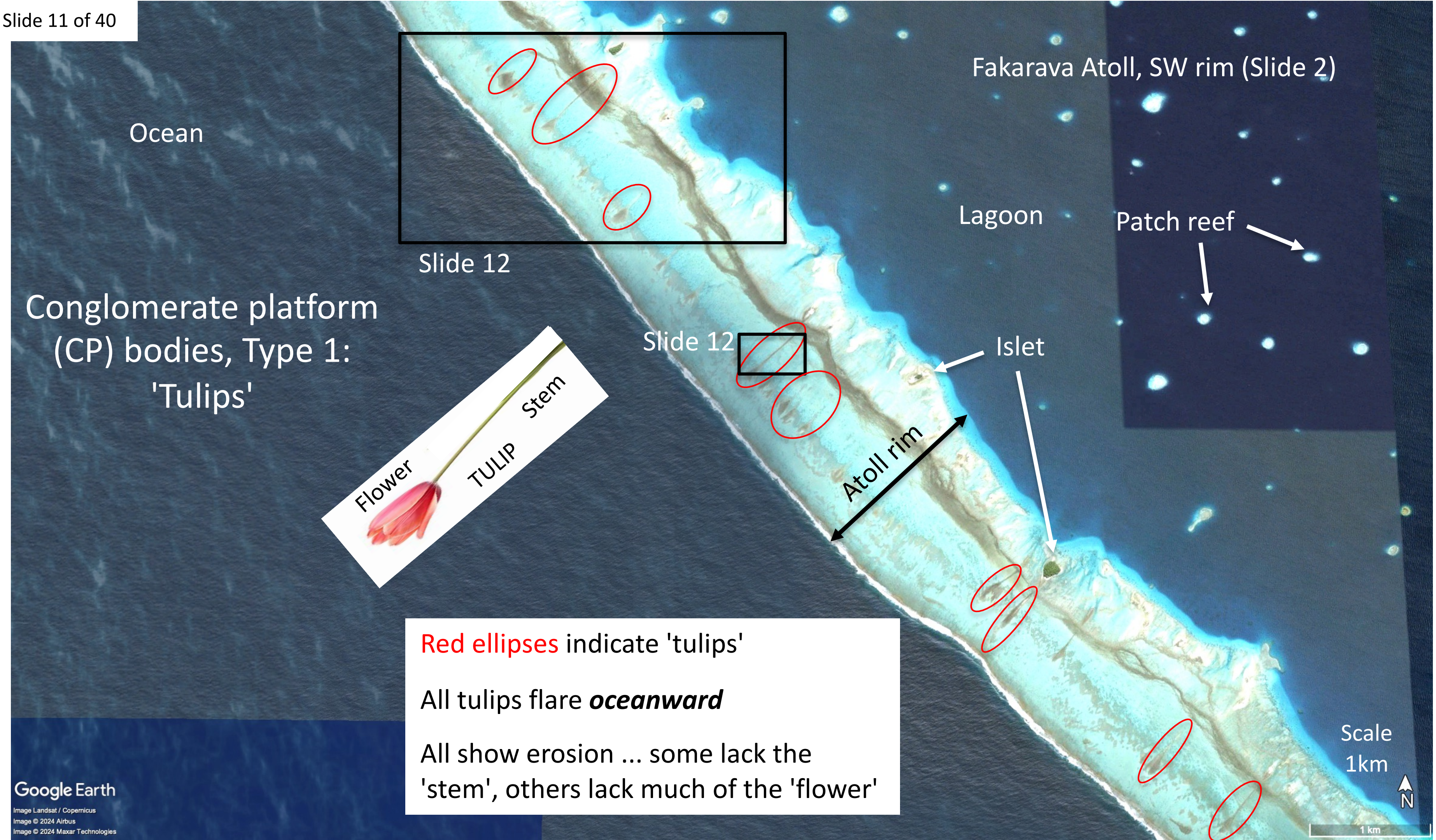
1. 'tulips', comprising a 'stem' and a 'flower'; flowers can merge sideways

2. fans (can merge sideways)

Both types can have perched islets

Both types flare oceanward (previously unreported?), i.e. derived from *lagoon*, not from atoll's oceanward flank ('fore-reef slope' in Slide 5).

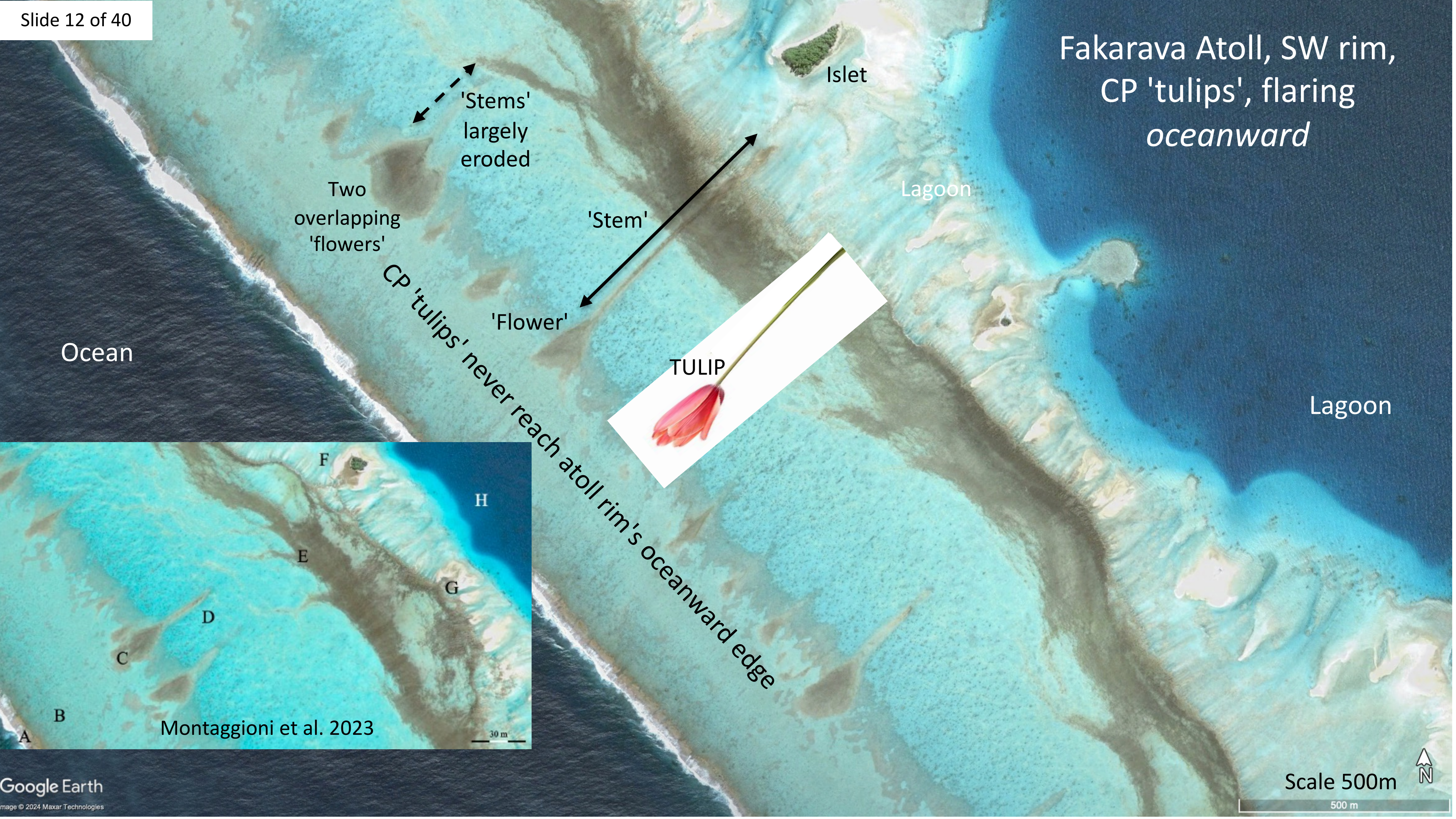
Conglomerate platform (CP) bodies, Type 1: 'Tulips'

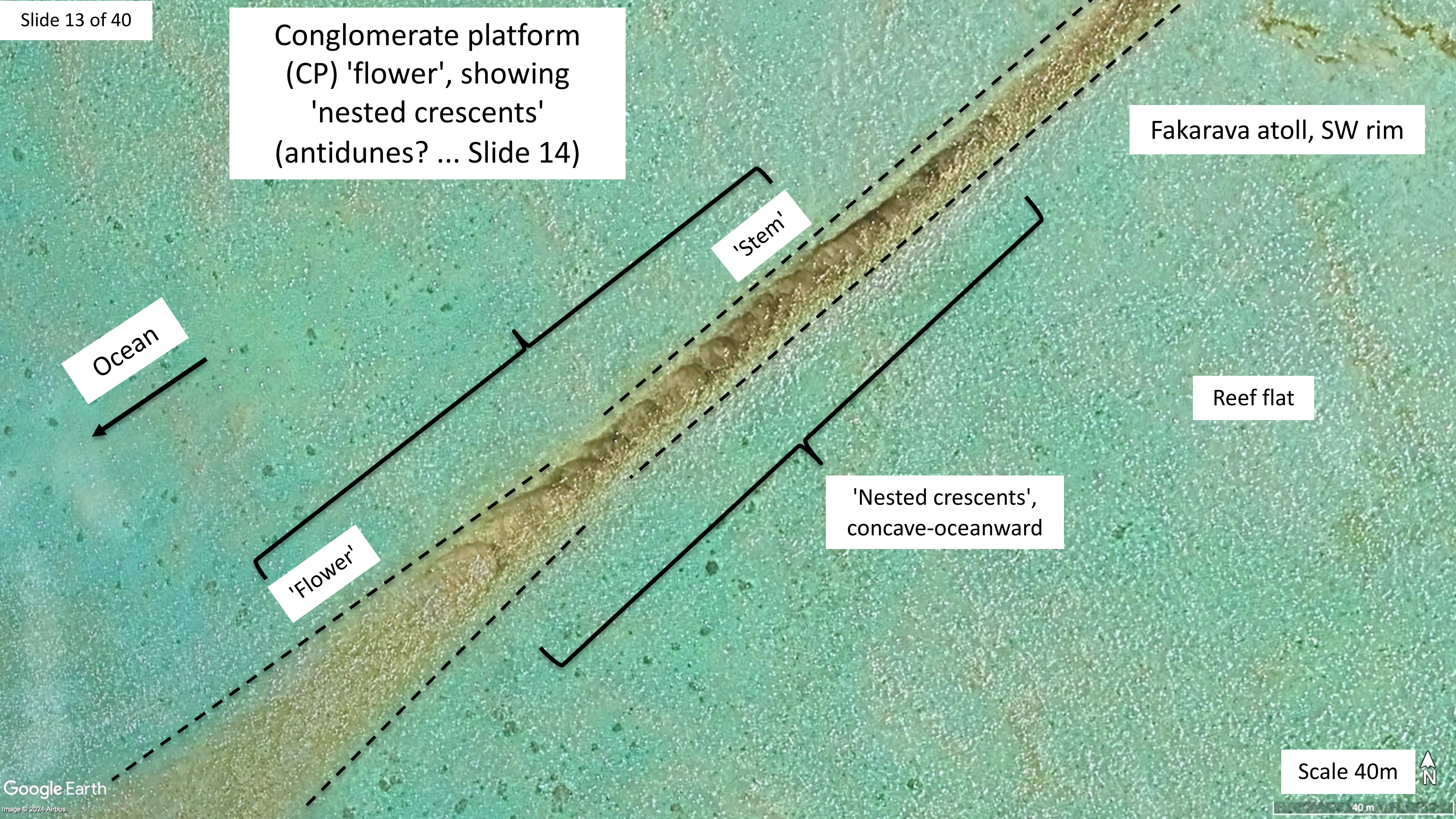


Red ellipses indicate 'tulips'

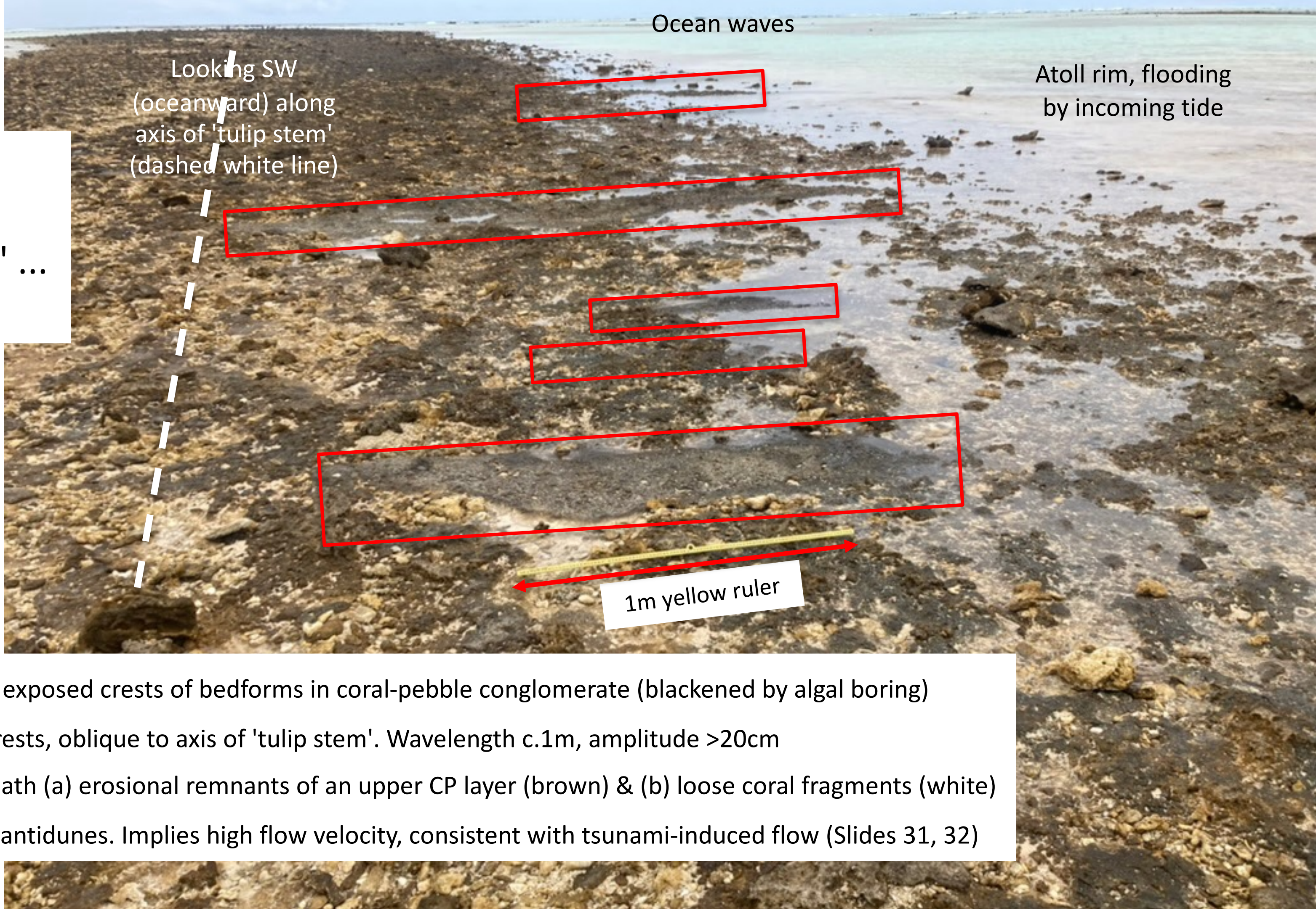
All tulips flare ***oceanward***

All show erosion ... some lack the 'stem', others lack much of the 'flower'


Fakarava Atoll, SW rim,
CP 'tulips', flaring
oceanward
Islet
'Stems'
largely
eroded
Two
overlapping
'flowers'
'Stem'
'Flower'
Lagoon
Lagoon
Ocean
TULIP
CP 'tulips' never reach atoll rim's oceanward edge
F
H
E
G
D
C
B
A
Montaggioni et al. 2023
30 m
Google Earth
mage © 2024 Maxar Technologies
Scale 500m
500 m
N


Conglomerate platform (CP) 'flower', showing 'nested crescents' (antidunes? ... Slide 14)
Fakarava atoll, SW rim
'Stem'
Ocean
Reef flat
'Nested crescents', concave-oceanward
'Flower'
Scale 40m
N
40 m
Google Earth
Image © 2024 Airbus

Conglomerate platform (CP) 'nested crescents' ... ground truthing



Red boxes indicate poorly exposed crests of bedforms in coral-pebble conglomerate (blackened by algal boring)

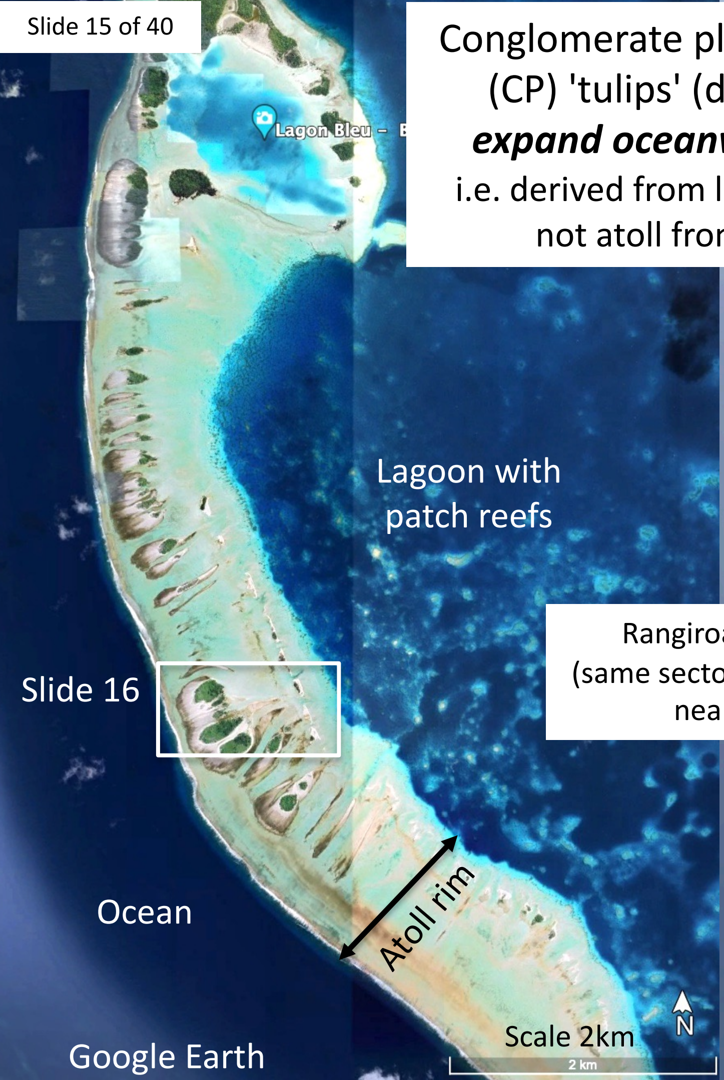
- Rounded, symmetrical crests, oblique to axis of 'tulip stem'. Wavelength c.1m, amplitude >20cm

- Troughs are hidden beneath (a) erosional remnants of an upper CP layer (brown) & (b) loose coral fragments (white)

Tentatively interpreted as antidunes. Implies high flow velocity, consistent with tsunami-induced flow (Slides 31, 32)

Conglomerate platform (CP) 'tulips' (dark) ***expand oceanward***

i.e. derived from lagoon, not atoll front



Rangiroa Atoll SW rim (same sector in both images), near Fakarava

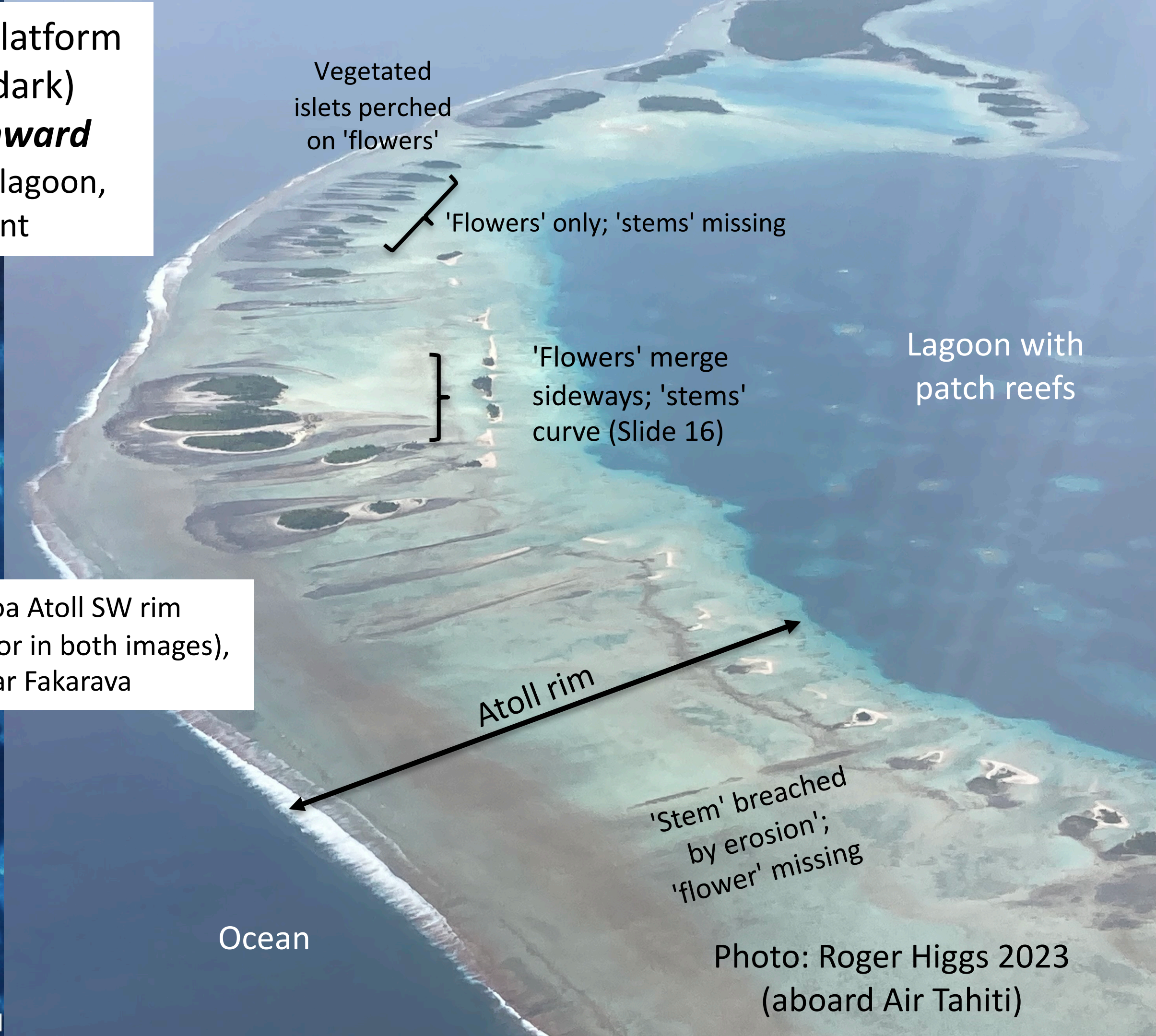
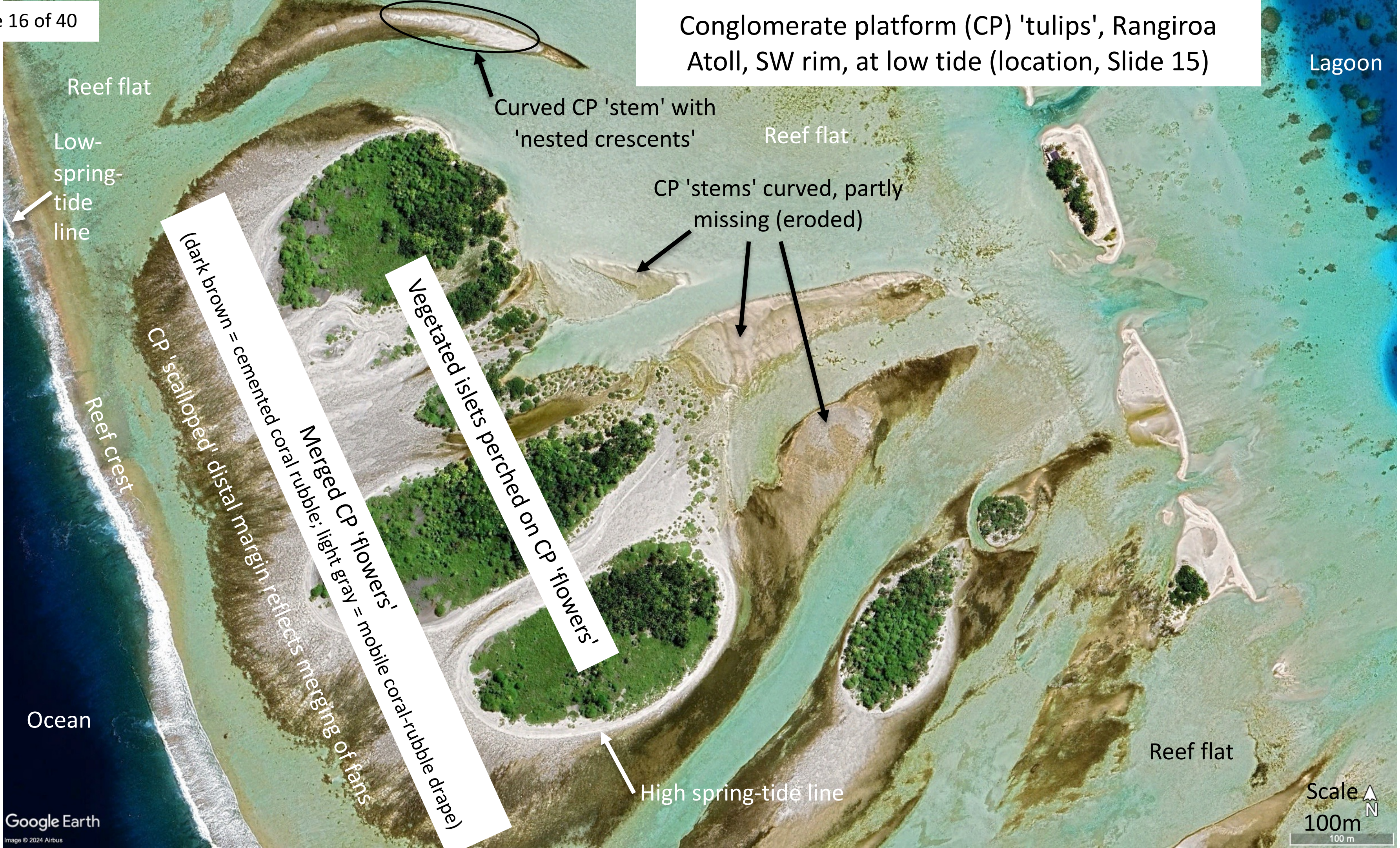


Photo: Roger Higgs 2023 (aboard Air Tahiti)

Conglomerate platform (CP) 'tulips', Rangiroa Atoll, SW rim, at low tide (location, Slide 15)

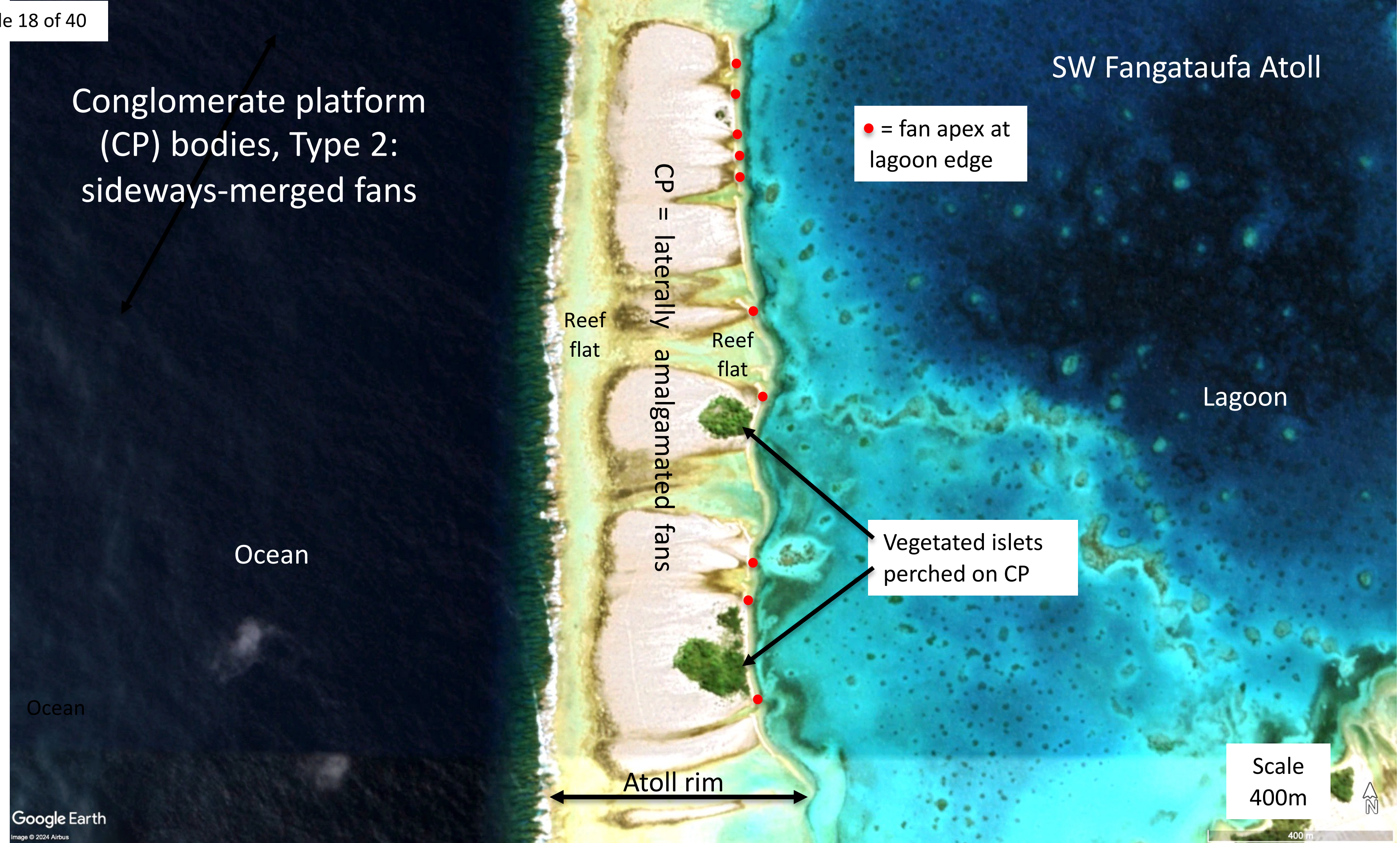


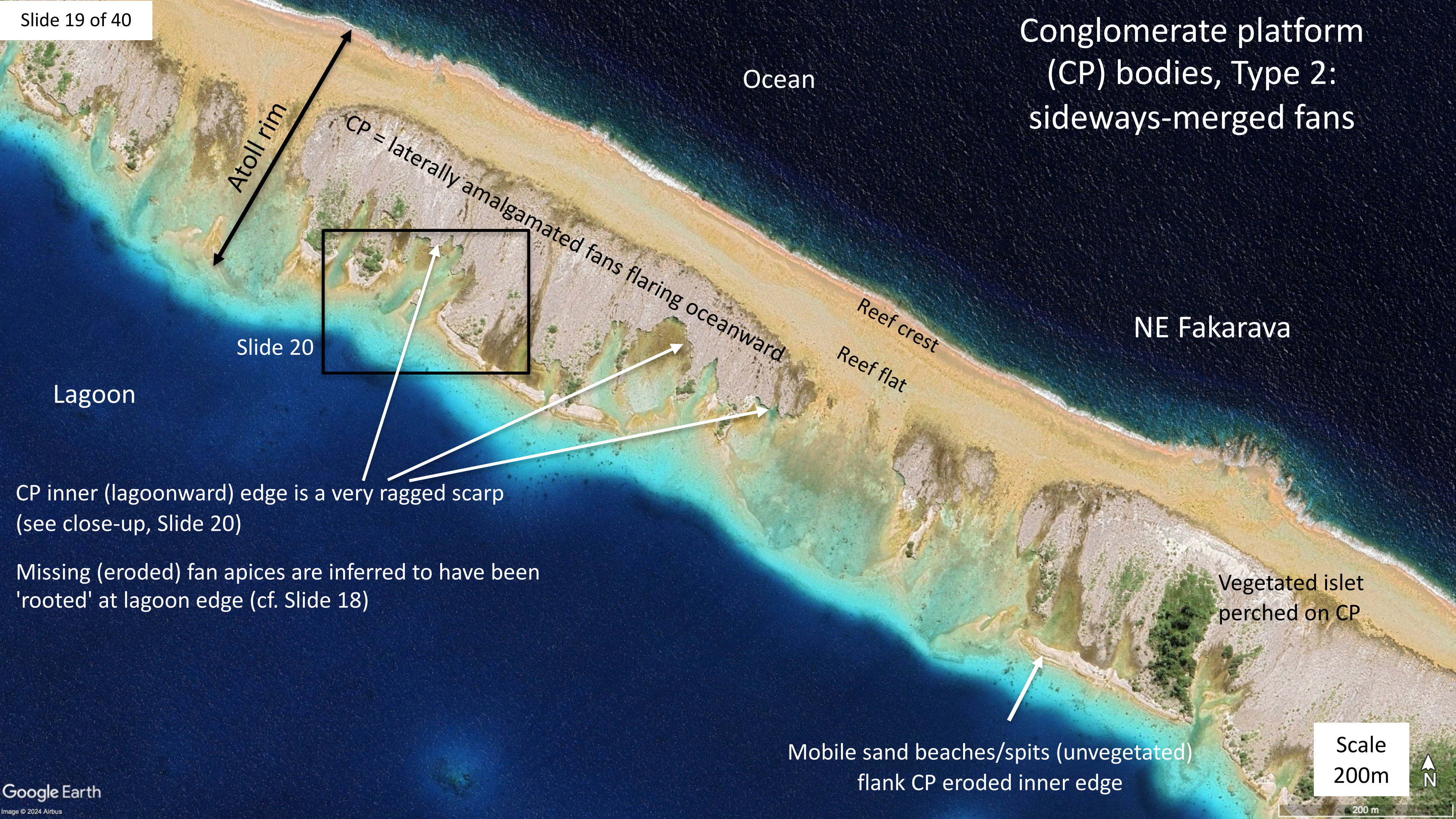
Oceanward-flaring 'tulips' occur on many other Pacific atolls, spanning a NW-SE distance of at least 6,000km (Majuro to Mururoa, Slide 4), including ...

Abemama, Apataki, Caroline (Slide 28), Fangataufa* (Slide 18), Hao, Majuro, Manihiki, Mururoa*, Nukufetau, Pukarua, Tarawa, Tikehau ...

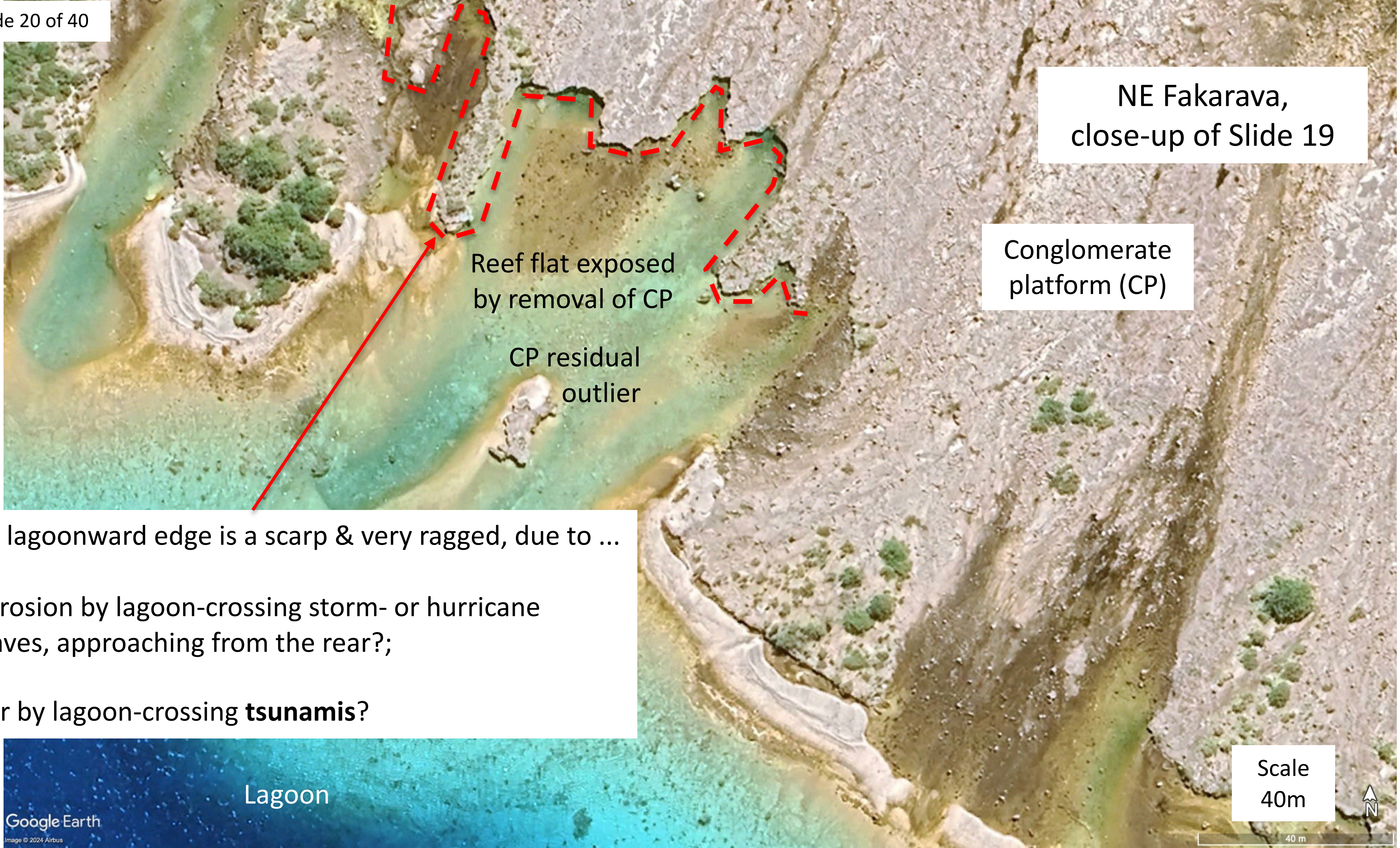
... search around their rims on Google Earth

* French former nuclear bomb test sites


Conglomerate platform
(CP) bodies, Type 2:
sideways-merged fans
SW Fangataufa Atoll
= fan apex at
lagoon edge
CP = laterally amalgamated fans
Reef
flat
Reef
flat
Lagoon
Vegetated islets
perched on CP
Ocean
Ocean
Atoll rim
Scale
400m
N
400 m
Google Earth
Image © 2024 Airbus


Conglomerate platform (CP) bodies, Type 2: sideways-merged fans
Ocean
Atoll rim
CP = laterally amalgamated fans flaring oceanward
Reef crest
Reef flat
NE Fakarava
Slide 20
Lagoon
CP inner (lagoonward) edge is a very ragged scarp (see close-up, Slide 20)
Missing (eroded) fan apices are inferred to have been 'rooted' at lagoon edge (cf. Slide 18)
Vegetated islet perched on CP
Mobile sand beaches/spits (unvegetated) flank CP eroded inner edge
Scale 200m
N
200 m
Google Earth
Image © 2024 Airbus

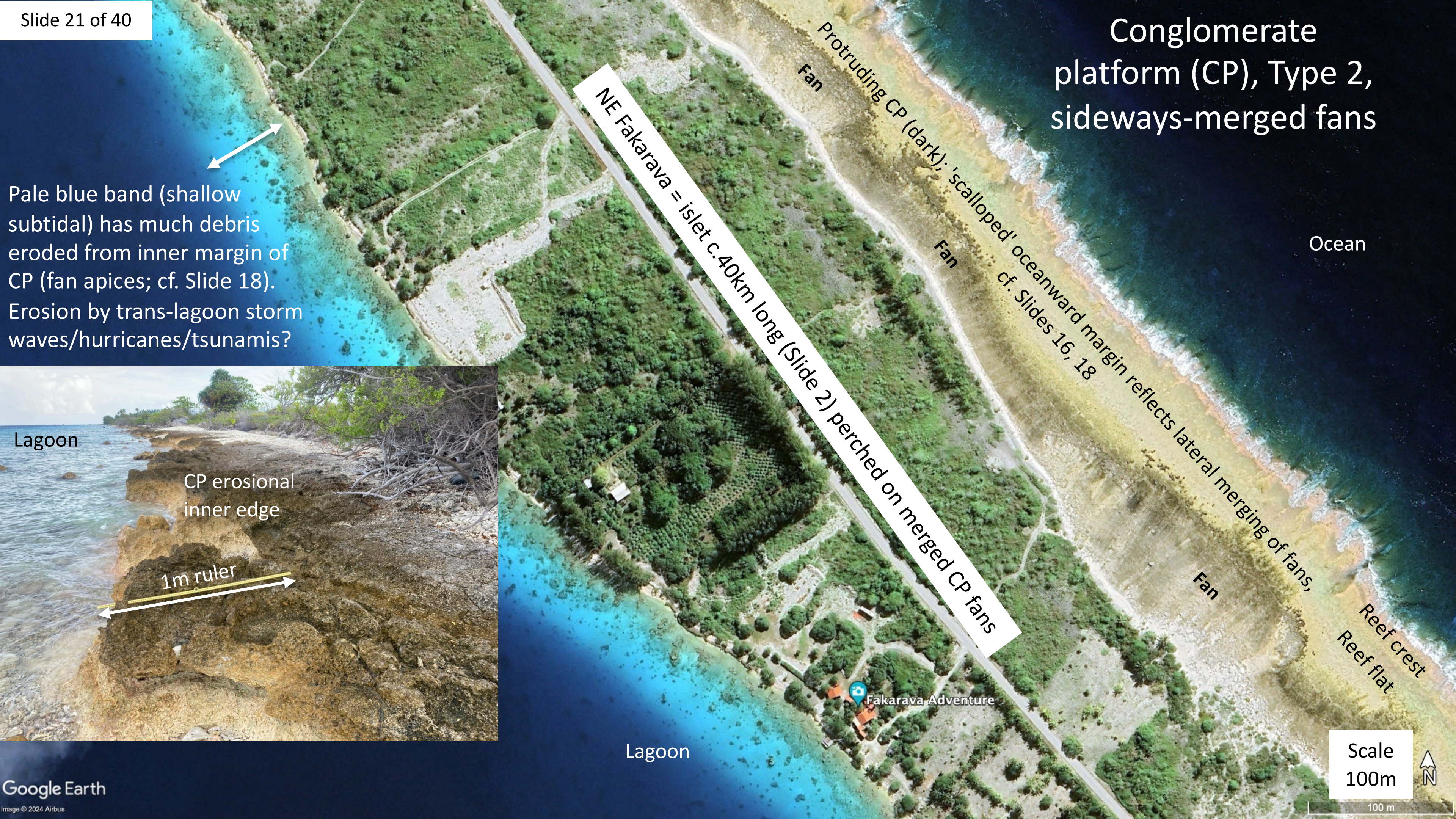
NE Fakarava, close-up of Slide 19



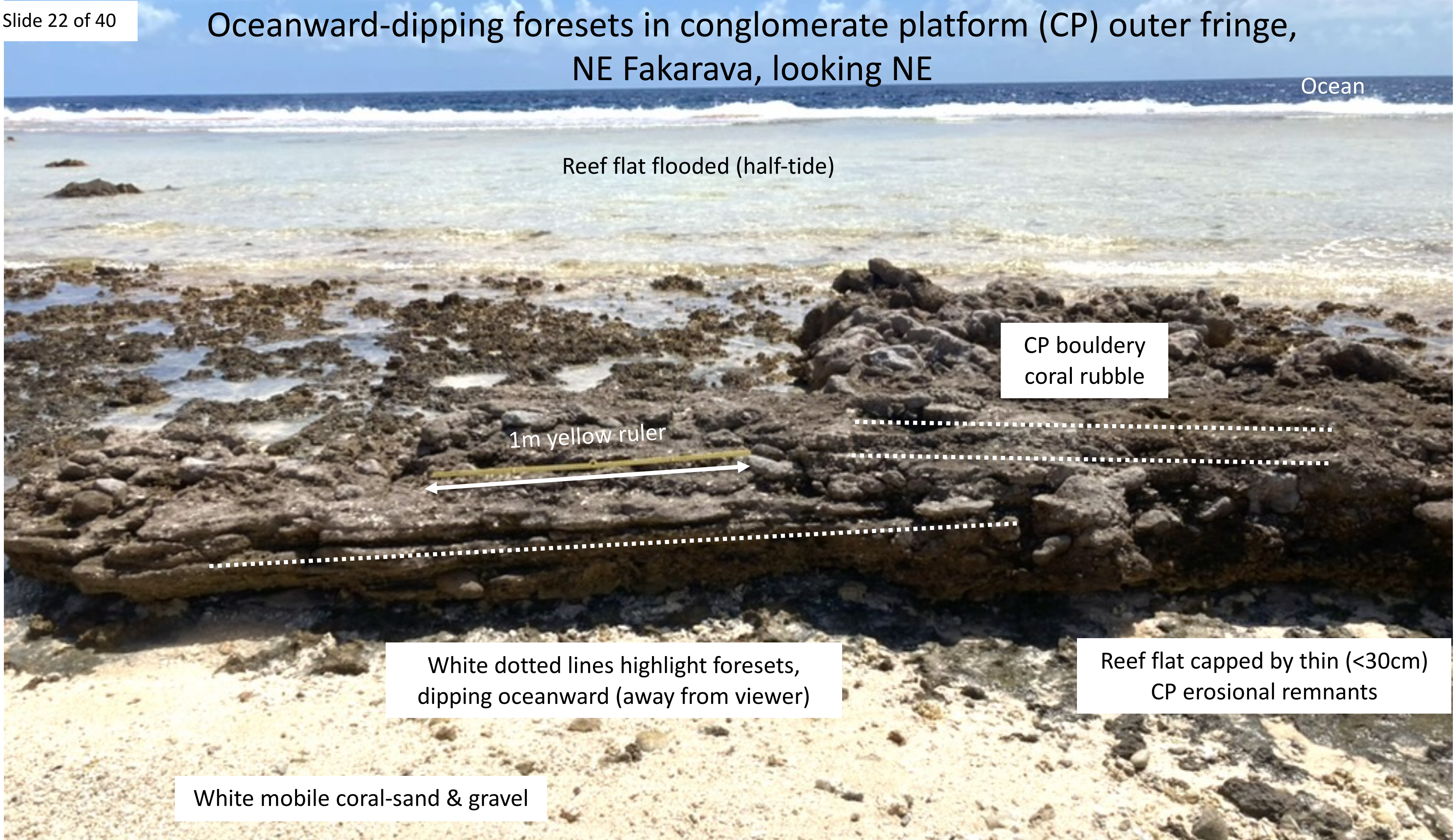
CP lagoonward edge is a scarp & very ragged, due to ...

- erosion by lagoon-crossing storm- or hurricane waves, approaching from the rear?;

- or by lagoon-crossing **tsunamis**?

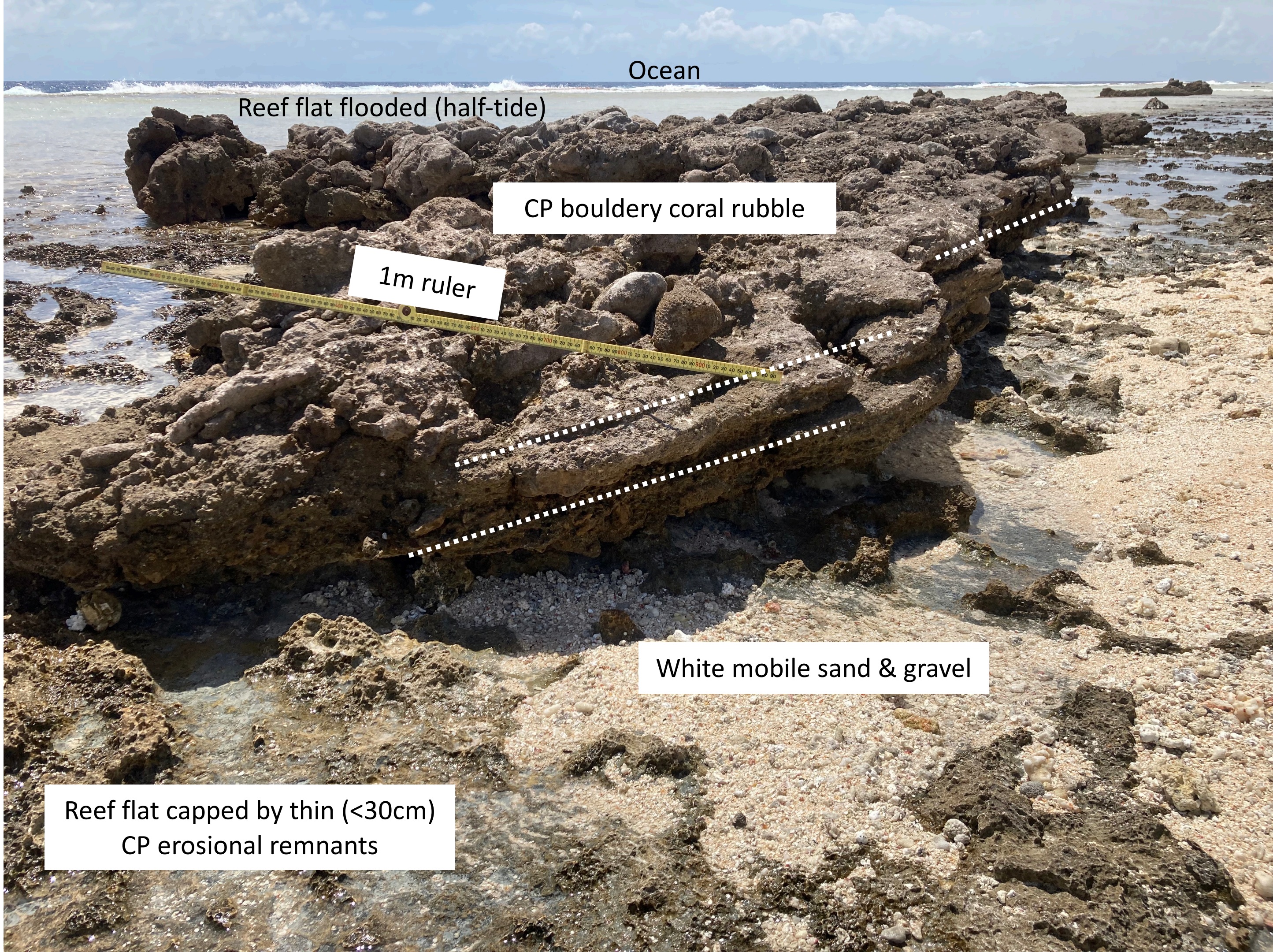

Conglomerate platform (CP), Type 2, sideways-merged fans
Pale blue band (shallow subtidal) has much debris eroded from inner margin of CP (fan apices; cf. Slide 18). Erosion by trans-lagoon storm waves/hurricanes/tsunamis?
NE Fakarava = islet c.40km long (Slide 2) perched on merged CP fans
Protruding CP (dark); 'scalloped' oceanward margin reflects lateral merging of fans, cf. Slides 16, 18
Fan
Fan
Fan
Ocean
Reef crest
Reef flat
Lagoon
Fakarava Adventure
Scale 100m
N
100 m
Google Earth
Image © 2024 Airbus
Lagoon
CP erosional inner edge
1m ruler

Oceanward-dipping foresets in conglomerate platform (CP) outer fringe, NE Fakarava, looking NE

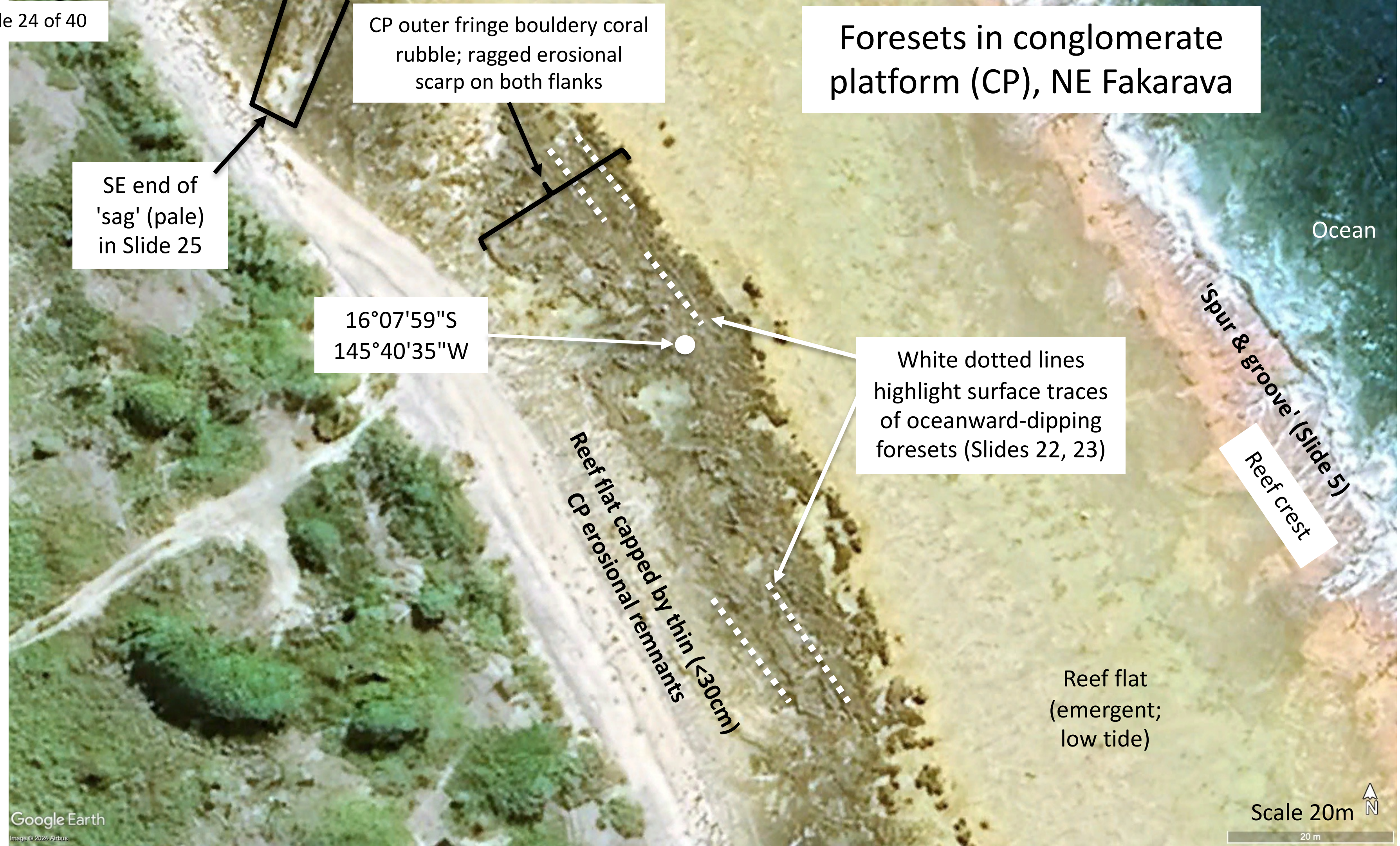


Oceanward-dipping foresets in conglomerate platform (CP) outer fringe, NE Fakarava, looking SE

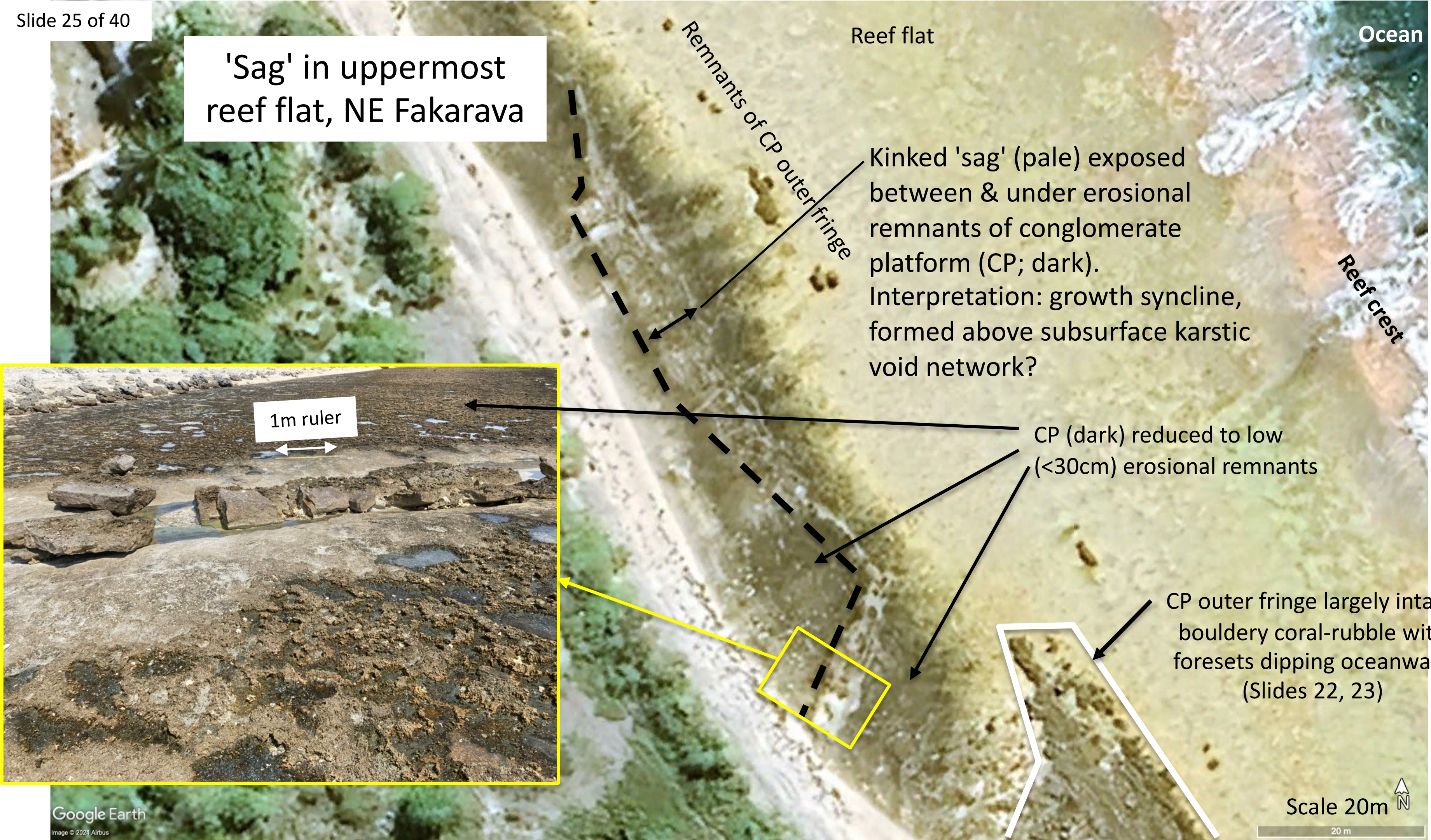
White dotted lines highlight oceanward-dipping foresets



Foresets in conglomerate platform (CP), NE Fakarava



'Sag' in uppermost reef flat, NE Fakarava



Conglomerate platform (CP) previous interpretation ...

Inward transport (from atoll's ocean-side 'reef front', by storms; Slide 9)

CP new interpretation ...

***Outward* transport** (from lagoon reefs).

Evidence ...

1. 'tulips' dilate ***oceanward*** (i.e. 'stem' expands into 'flower'; Slides 11-13, 15, 16, 28); likewise fans (Slides 18, 19, 28)

2. foresets dip ***oceanward*** (Slides 22, 23)

3. 'flowers' never reach outer (oceanward) edge of atoll rim (Slides 11, 12, 15, 16, 28); neither do fans (Slides 18, 19, 21); 'scalloped' fronts (Slides 16, 18, 21) suggest this is not simply due to erosion

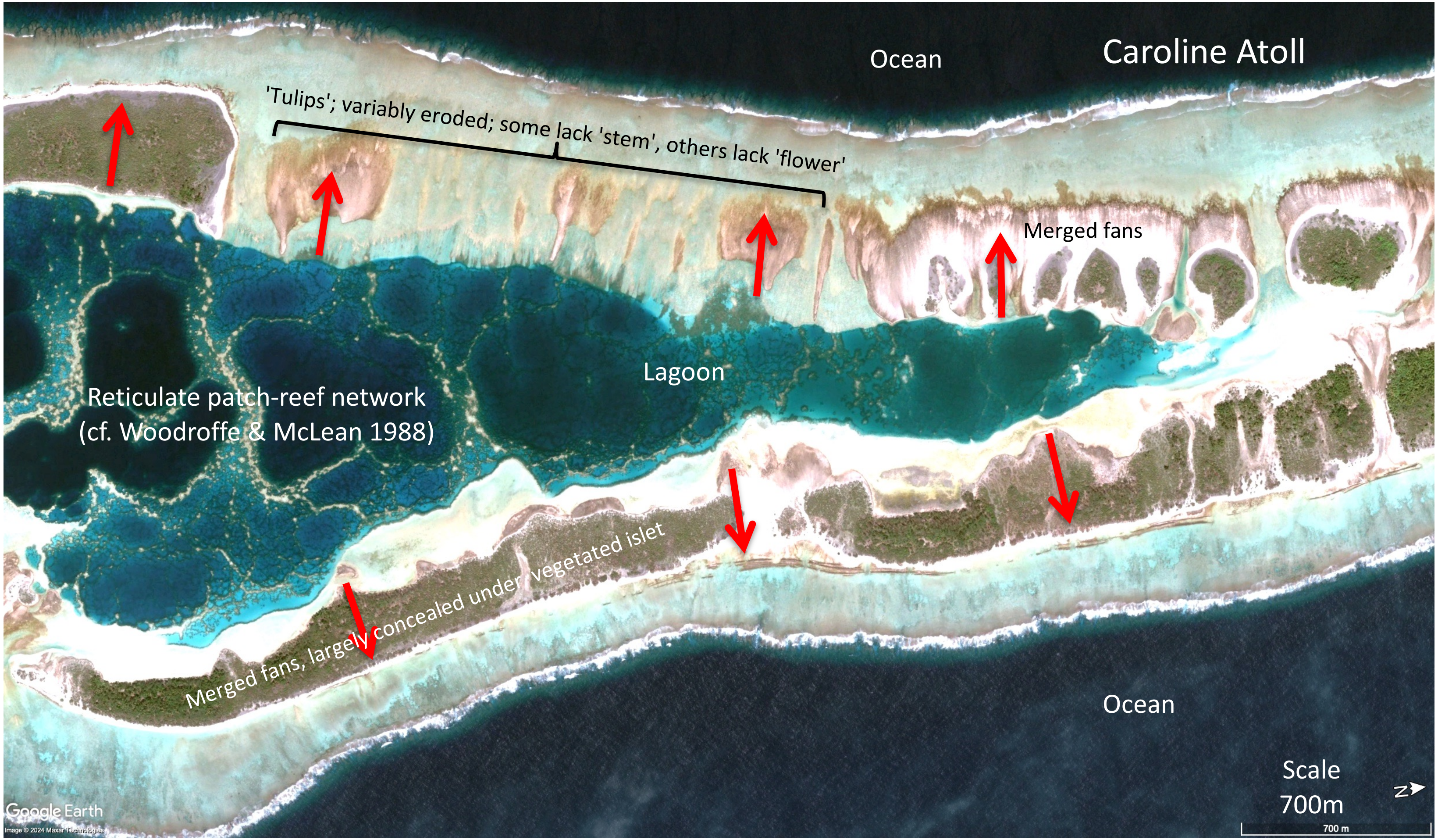
4. 'stems' may meet inner (lagoonal) edge of atoll rim (Slide 28)

5. CP can cap intra-lagoon patch reefs (Montaggioni et al. 2021)

Fakarava research supports Higgs 2022 (GSA annual meeting, abstract & slideshow) model of conglomerate platform origin

... next 6 slides

Higgs 2022 model:
Conglomerate platform (CP) fans & 'tulips' comprise coral rubble bilaterally ejected from lagoon



How is CP coral rubble ejected bilaterally from lagoon?

Higgs (2022)
proposed ***outward*** transport of coral rubble from lagoon patch-reef talus,
by ***tsunami-***induced vortices, after a rapid SL rise drowned the atoll rim,
removing islets (wave attack/ravinement)

A tsunami impinging on a *drowned* atoll

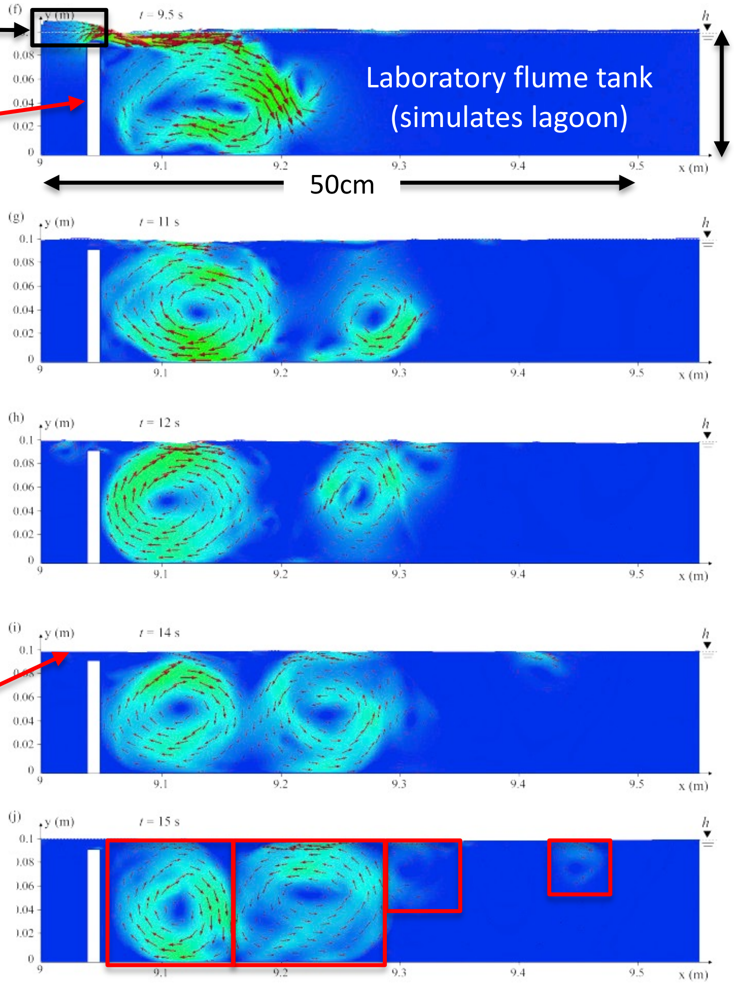
(i.e. an underwater barrier)

has two theoretical effects ...

Tsunami effect 1 …

lagoon vortices

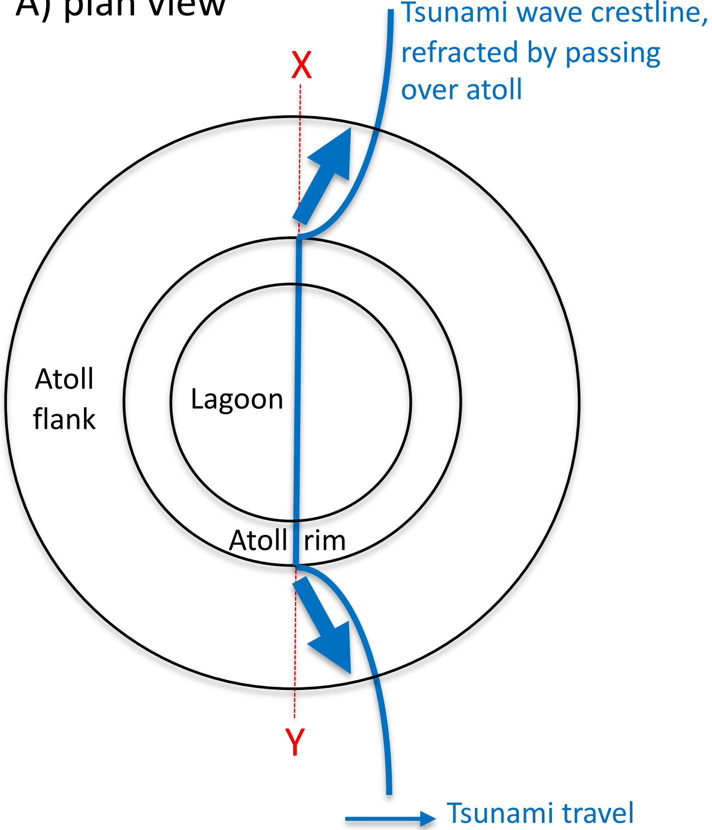
Boshenyatov & Zhiltsov 2019



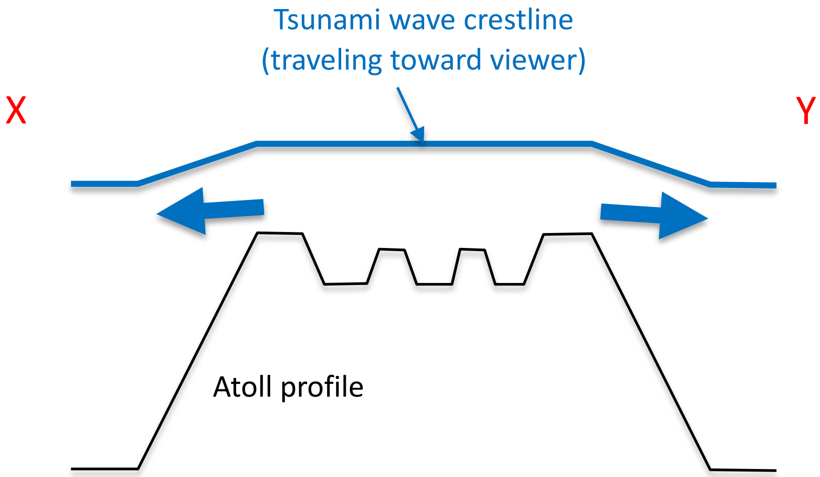
Tsunami effect 2 ... outward pressure gradient

Schematic atoll (not to scale) ...

A) plan view



B) cross section X-Y



= decreasing tsunami height; creates bi-lateral pressure gradient

In combination ...

vortices + pressure gradient cause transportation

of patch-reef coral rubble outward from the lagoon

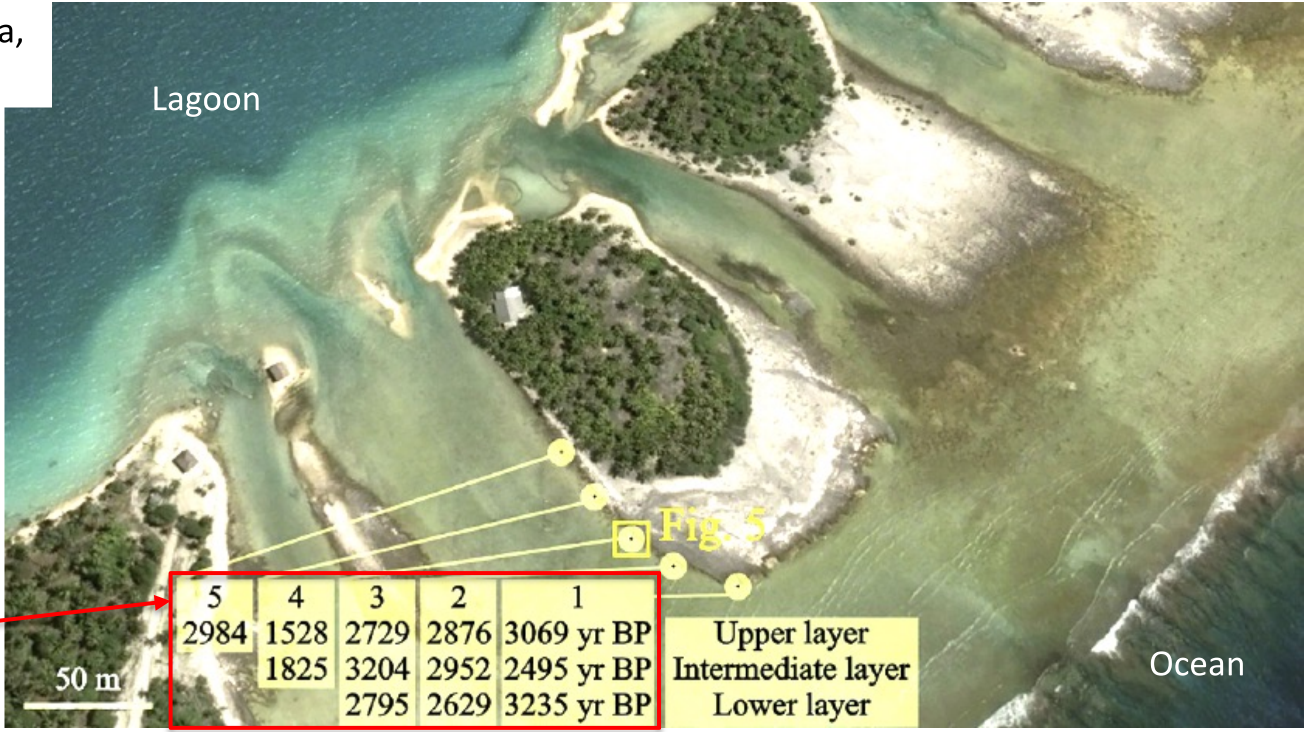
& deposition on the atoll rim

When was the tsunami?

c.2.5kyBP (*very* approximate), based on conglomerate platform (CP) coral-clast age span ...

Pacific CP coral-clast ages mostly 6.5 - 2.5kyBP (literature search)

e.g. Takapoto Atoll, near Fakarava,
Montaggioni et al. 2021



Dated coral clasts
in CP edge (scarp)

Proposed Pacific atoll history since 3kyBP
(largely from Higgs 2022)

Around 3kyBP, atoll rim was subaerially exposed for centuries (global 'Pelham Bay Emergence'; lowstand c.3m below modern mean SL; see 'Fairbridge Curve' in Slide 37).

About 2.7kyBP, world sea level (SL) *quickly* rose ('Abrolhos Submergence', Slide 37) c.5m in c.100y (cf. proven *previous*-interglacial 2-3m SL rise in <100y; Blanchon 2011), removing sand-gravel islets (wave attack) and outpacing coral growth, thus reflooding the atoll rim (reef flat).

After the rise, the first-arriving tsunami grew in height as it crossed the atoll rim and, in the lagoon, induced vortices, ejecting patch-reef talus bilaterally 'sideways' onto the rim, depositing coral-rubble fans and 'tulips' (later cemented to form conglomerate platform [CP]), thus shallowing the water, preventing a further tsunami-ejection event.

NB present-day atoll rims, even at high tide, are very shallow (<c.1m; CP & reef flat) or emergent (islets), so tsunamis passing between islets do not grow in height significantly (cf. Rasheed et al. 2024 fig. 10).

By c.1.7kyBP, SL fell c.5m ('Florida Emergence'), exposing reef-flat and lagoon-fringe foraminiferal sand, causing it to be heaped into eolian dunefields (e.g. Kayanne et al. 2011 atoll sand composition).

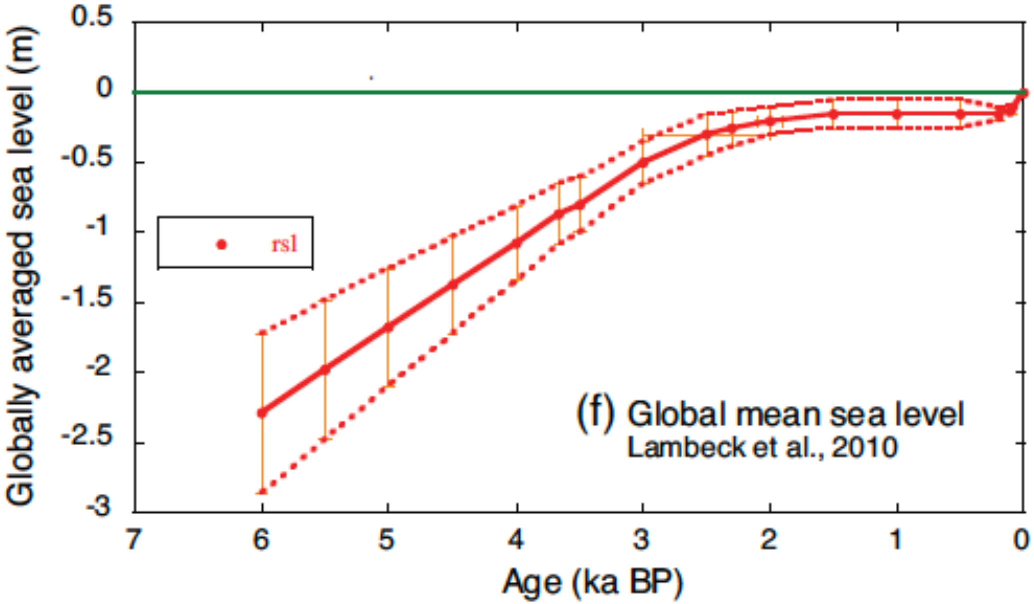
By 1.0kyBP, SL rose c.3m ('Rottnest Submergence'), re-flooding the reef flat and shrinking the dunefields (wave attack) to form today's islets.

Relevance of this atoll study ...

1. Contradicts IPCC's belief that:

- no sea-level (SL) oscillation exceeded 1m in last 6ky (none >0.5m in last 3ky)

- since 6ka, SL was never higher than today

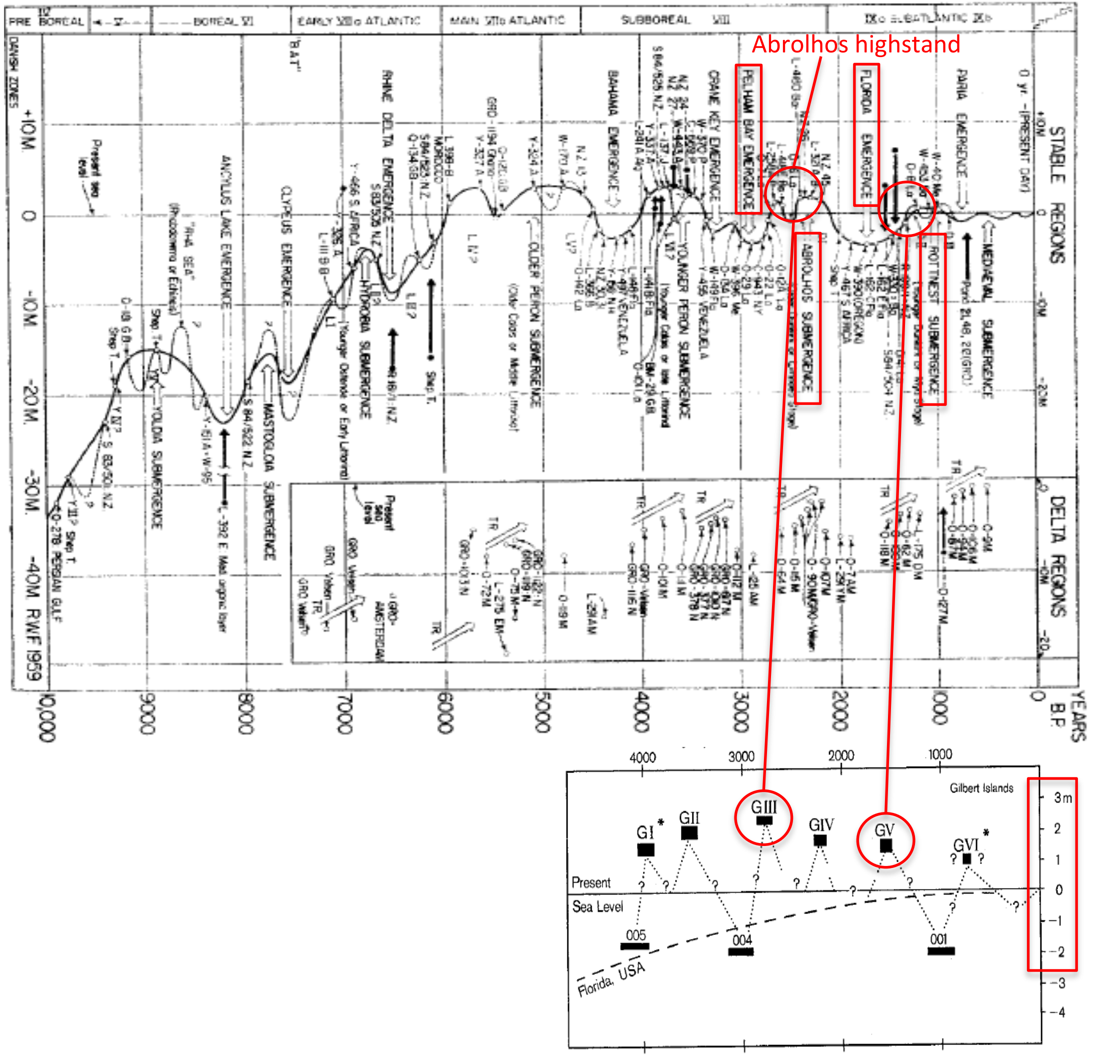


IPCC 2013 fig. 5.17f
(Fifth Assessment Report)

Relevance of this atoll study (cont'd) ...

2. Supports global Holocene 'Fairbridge Curve', with rapid meter-scale sea-level (SL) rises & falls (Fairbridge 1961, fig. 15), *unrelated to atmospheric CO2*

3. Supports Schofield (1977a) oscillating SL curve for Pacific atolls, with rapid meter-scale SL rises & falls



Relevance of this atoll study (cont'd) ...

4. Supports conclusion that subaerial (i.e. habitable) atoll islets only *exist* thanks to c.1-2m of Holocene SL fall (Schofield 1977b; Dickinson 2009; Kayanne et al. 2011)

5. Supports reality of Fairbridge's 'Rottnest Submergence' (Slide 37), shown by British archaeological evidence to have totaled c.3m in only c.70y (c.430-500AD), correlating with an exceptional Arctic warm-spike (probably induced by a known solar surge c.100y earlier), portending an imminent multi-meter SL rise due to even greater 21st Century, man-made, Arctic warmth (Higgs 2024)

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AIR TAHITI

Thank you !


HINANO
BRASSÉE PAR BRASSERIE DE TAHITI S.A.
DEPUIS 1955
TAHITI