The Comondú Arc-Gulf of California Rift Transition: Part I - Geology and Geochronology

(Part II – Geochemistry – in following talk by Keith Putirka)

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….and the Baja Basins college juniors who participated in our NSF-REU (2014-2018) and our NSF-IRES (2018-2023).

In the field in Baja California.

Research supported by NSF Research Experience for Undergraduates Grant 151120 to Niemi and Busby, a UC-MEXUS-CONACYT award to Busby and López-Martínez, and NSF-EAR-1917361 to Busby and Putirka.

At GSA meeting.

In camp.

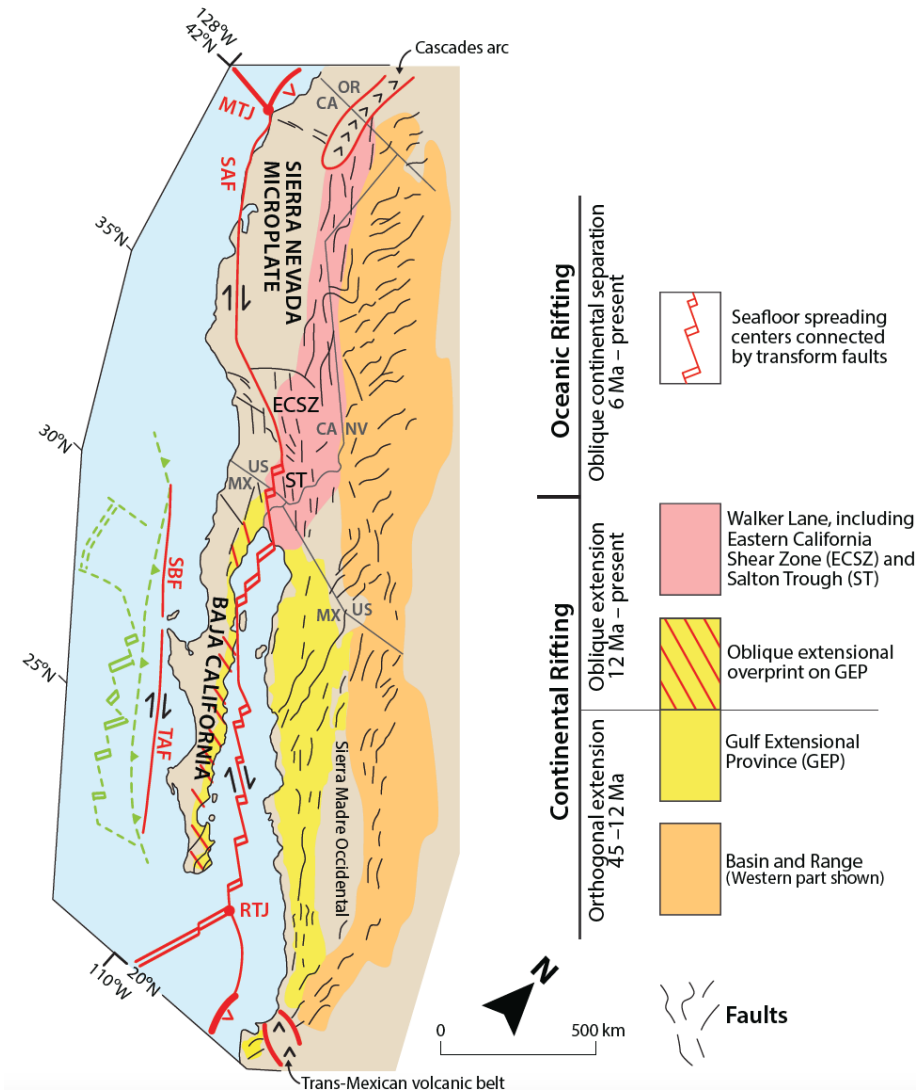
At the taco stand.

Tectonic setting of the arc-rift transition, Gulf of California

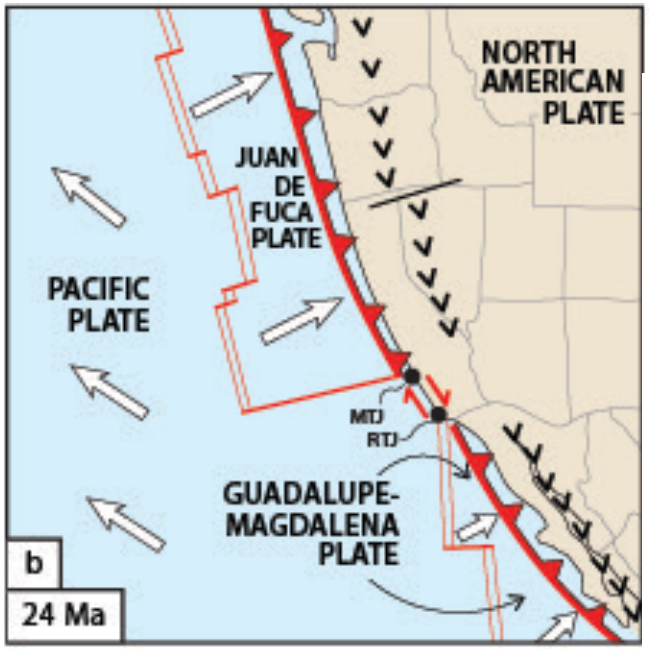
Walker Lane-Gulf of California oblique rift formed in the axis of the Comondú and Ancestral Cascades arc,

at the western edge of the Basins and Range and Gulf Extensional Province.

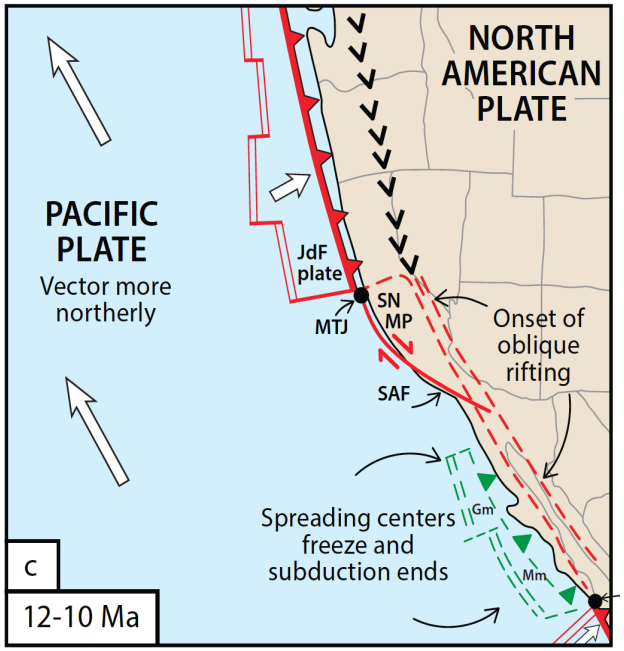
Busby and Putirka, 2025



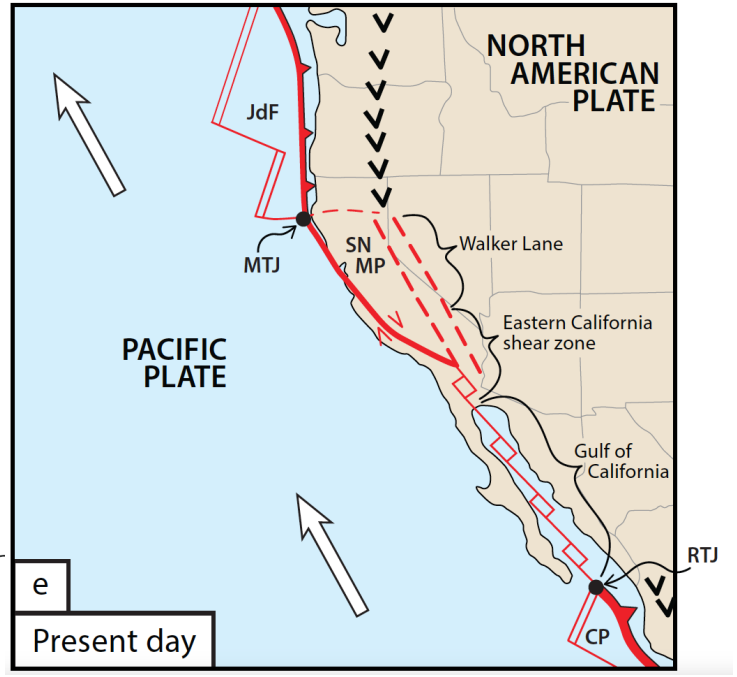
Tectonic setting of the arc-rift transition, Gulf of California, continued.
Busby and Putirka, 2025



24 Ma: Ancestral Cascades arc in U.S., and Comondú arc in Mexico

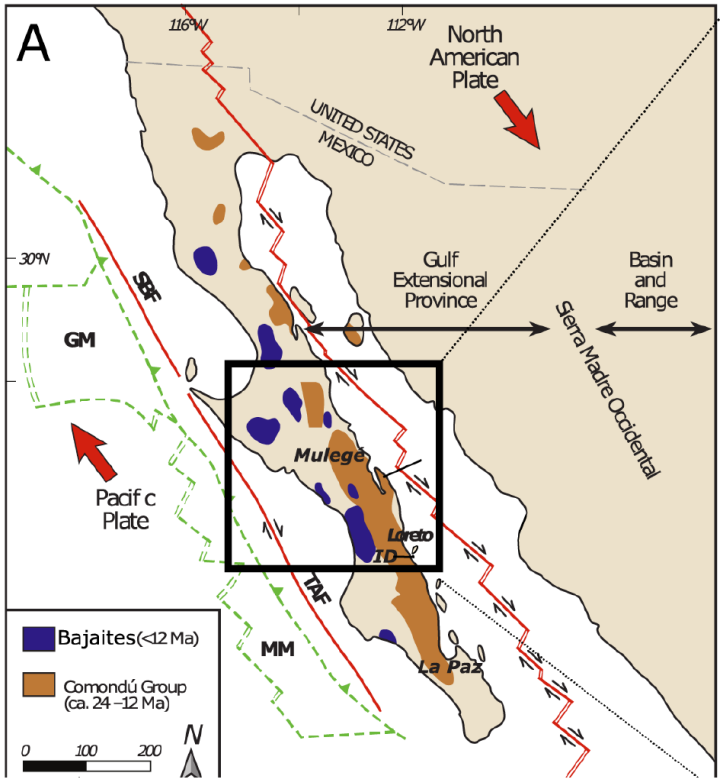


12 Ma: Onset of oblique rifting in the axes of both arcs, due to a change in the direction of the Pacific plate vector.



Gulf of California opens all at once, while Walker Lane is unzipping northward with time.

THIS TALK and the PUTIRKA AND BUSBY talk that follows: Arc magmatism switches to rift magmatism at 12 Ma in Central Gulf of California. WHAT DOES THE ARC-RIFT TRANSITION LOOK LIKE?



Busby et al., 2020

Cenozoic magmatism in Baja California

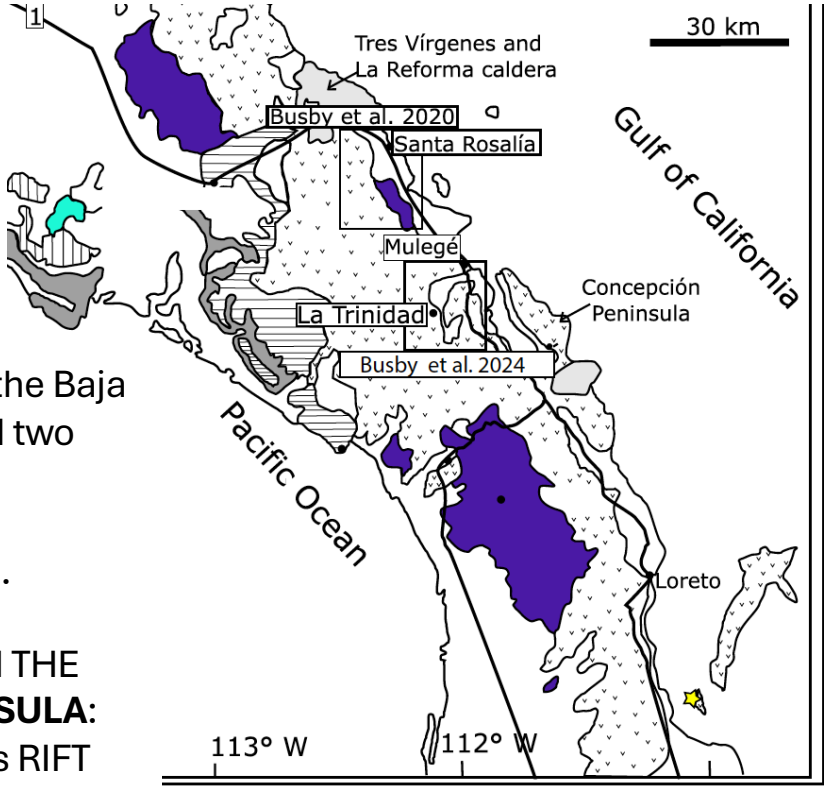
Bajaites – post-subduction (<12 Ma) "slab window" (blue).

Brown – widely shown as Miocene arc volcanic rocks BUT.....

..... It is largely undivided – see huge stippled area.....

The volcanology group of the Baja Basins REU has published two papers in this large area: Santa Rosalía (2020) and La Trinidad-Mulegé (2024).

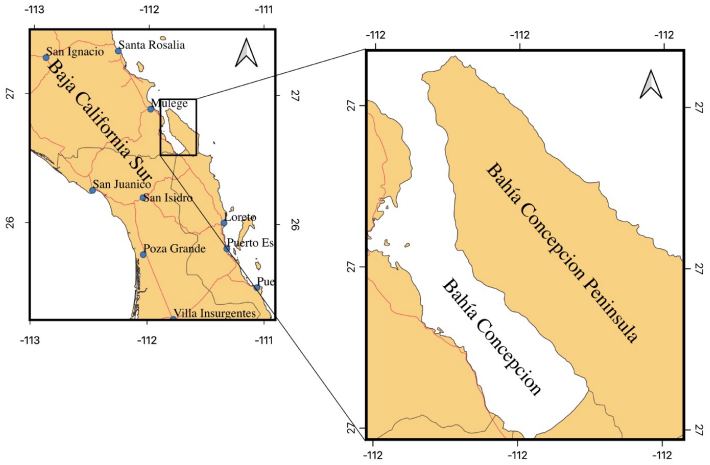
WE REPORT HERE ON THE **CONCEPCION PENINSULA**: Upper half of section is RIFT (not arc).



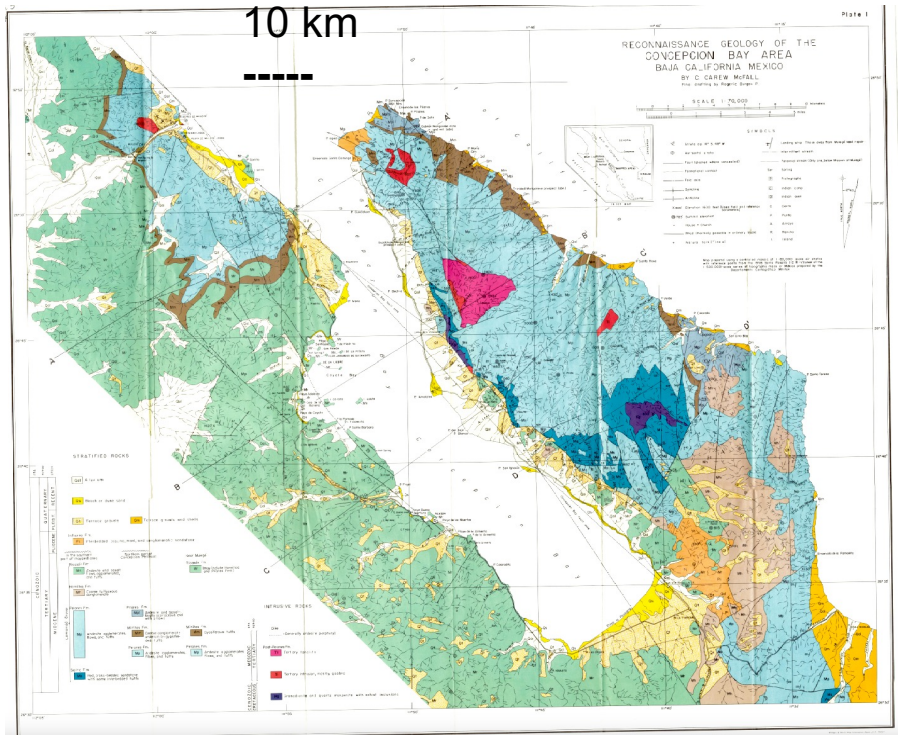
Busby et al., 2024

Concepción Peninsula:
50 km long, rugged and dry, mostly accessible only on foot, with limited access points by boat or 4WD – but exposure is AMAZING!!!.

We report on the NSF-REU mapping and sampling in the northern part and southern parts, which differ.
Central part needs work to be able to relate the two sections.

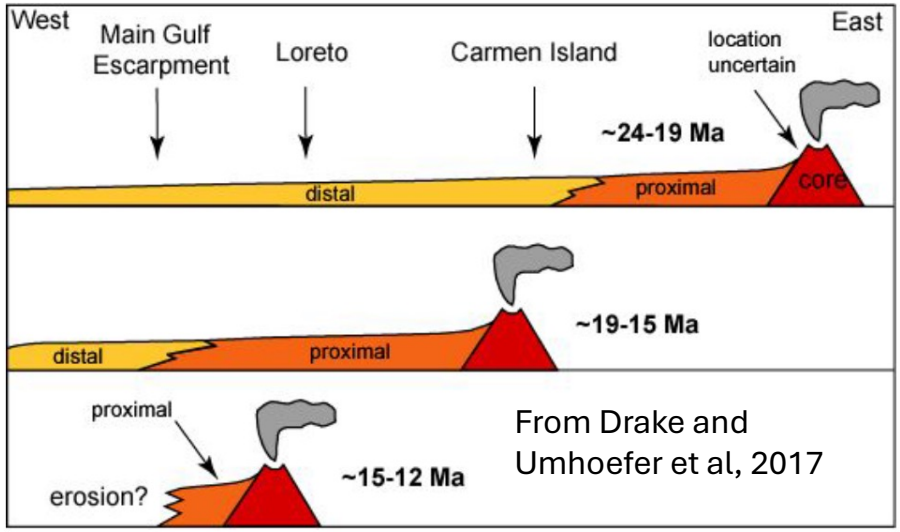


Mulegé - Concepción region not mapped since 1968 by McFall, who called all of it Miocene Comondú Group, except for sparse basement rocks shown in purple.



4. RIFT VOLCANIC ROCKS FORM THE UPPER HALF OF THE SECTION.

Our new mapping, $^{40}Ar/^{39}Ar$ geochronology and geochemistry:



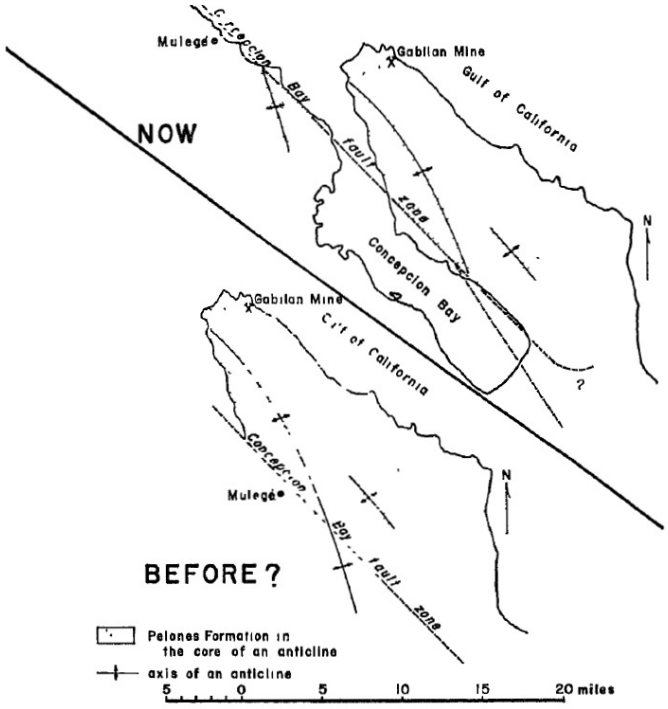
1. Distal forearc - Oligocene sedimentary rocks and distal silicic ignimbrites (Lower Comondú Group).

2. Proximal forearc - Early Miocene volcanic debris flow deposits (Middle Comondú Group).

3. Arc axis - Middle Miocene (Upper Comondú Group).

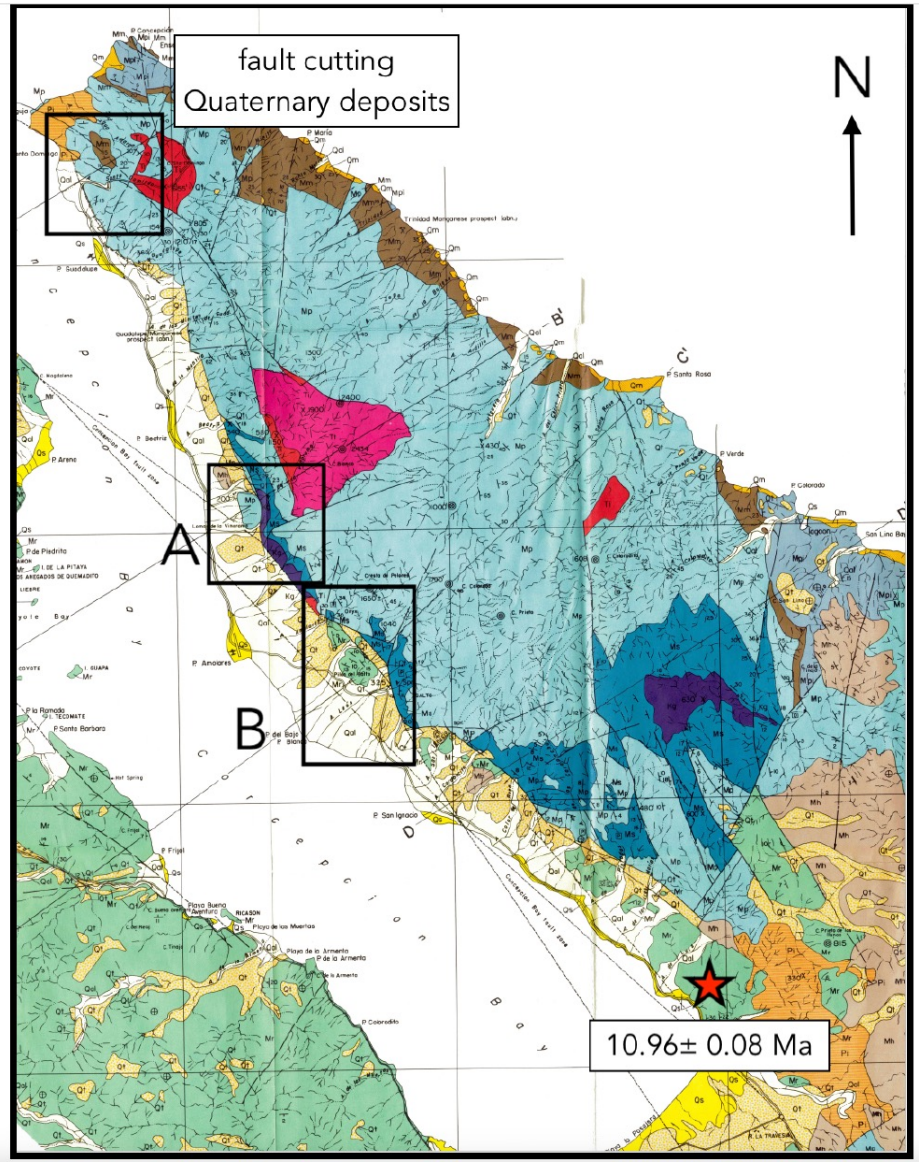
DUE TO SLAB ROLLBACK

Structural setting of the Concepión– Mulege region.



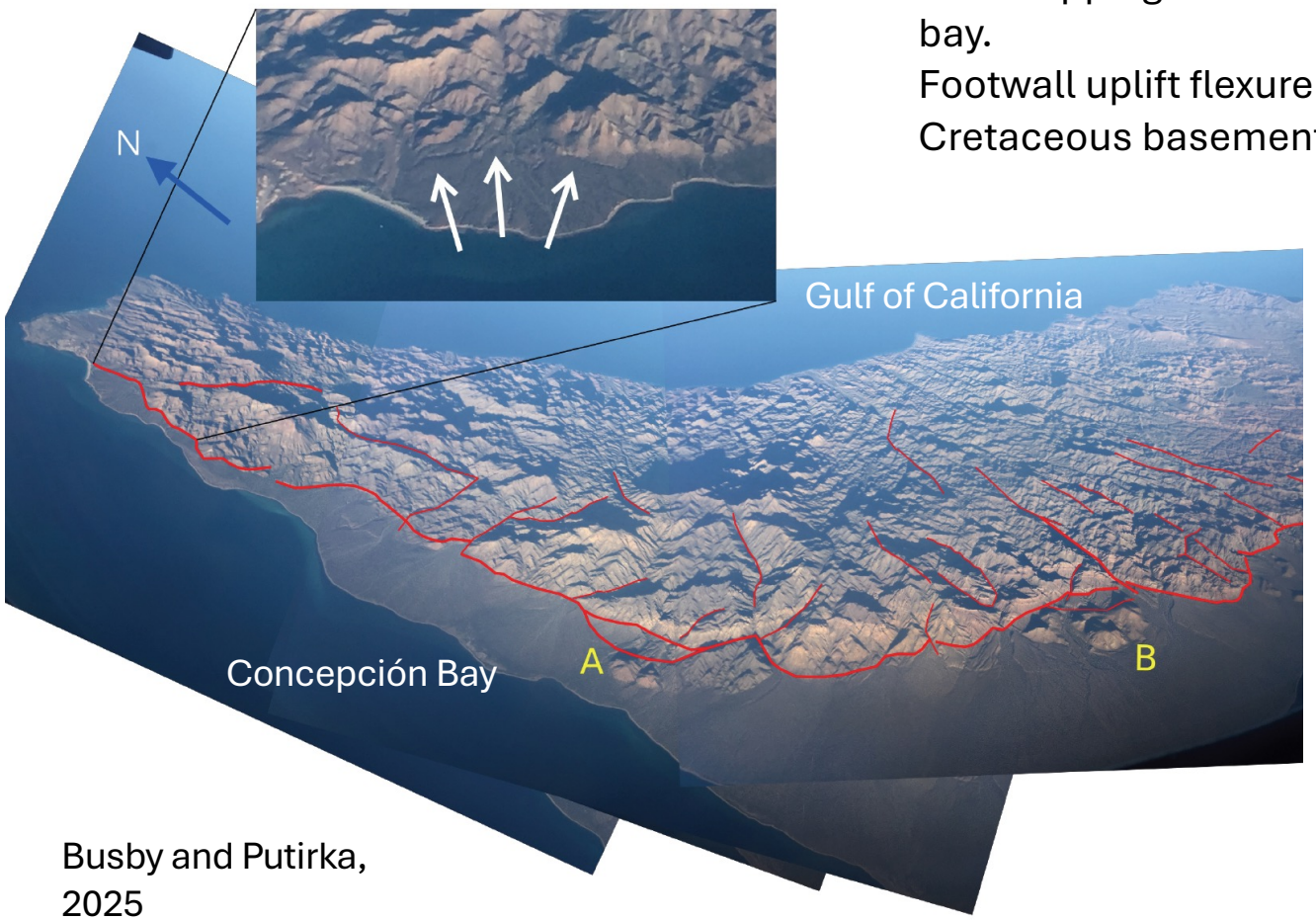
McFall (1968) inferred that a strike slip fault ran through the length of Concepción Bay, but that is wrong.

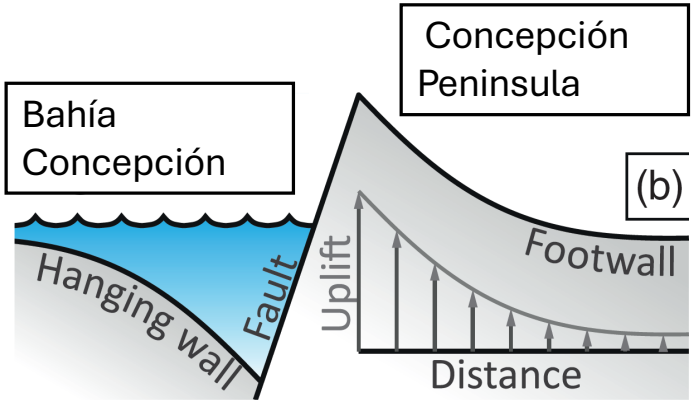
The west side of the Concepción Peninsula is bounded by west-dipping normal faults that bring up basement in the footwall, and drop the hanging wall below sea level (Concepción Bay).



Structural setting of the Concepción– Mulege region, continued.

Oblique aerial photomosaic of the Concepción Peninsula looking east:
West-dipping normal faults drop hanging wall below the bay.
Footwall uplift flexure exposes east-dipping section: Cretaceous basement, Oligocene, Miocene and Pliocene.

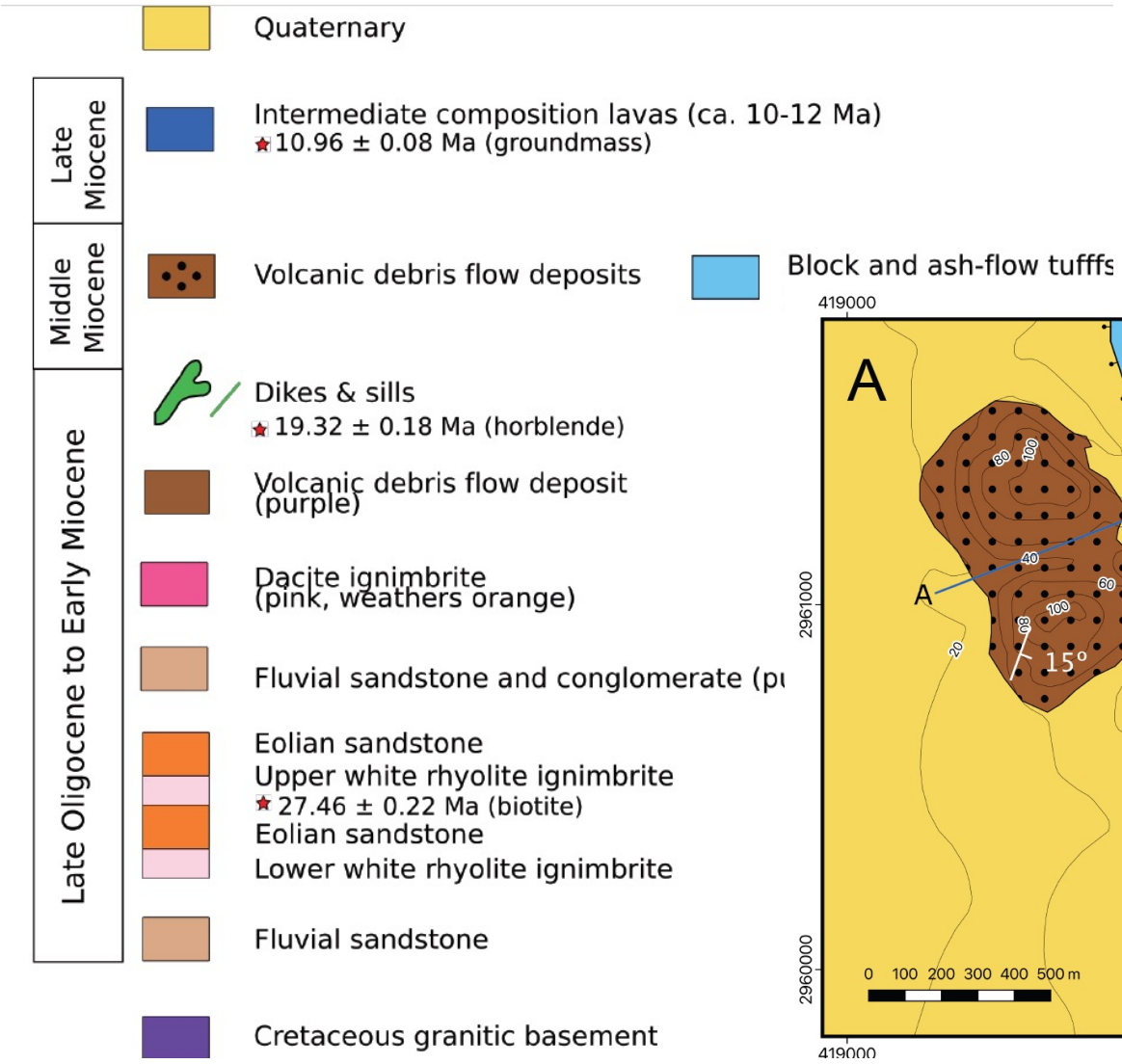


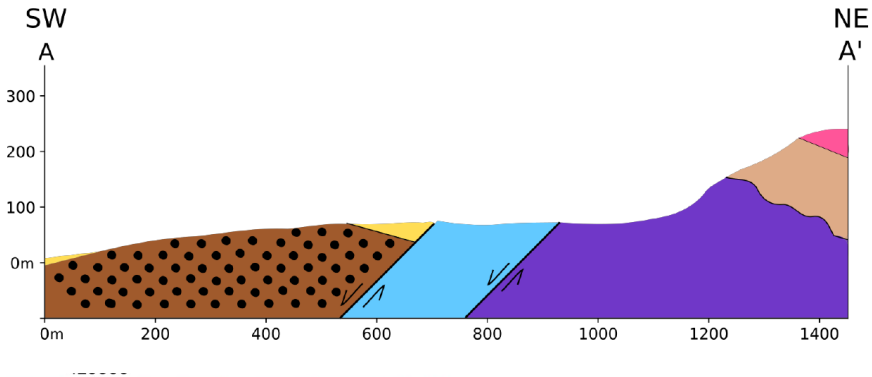


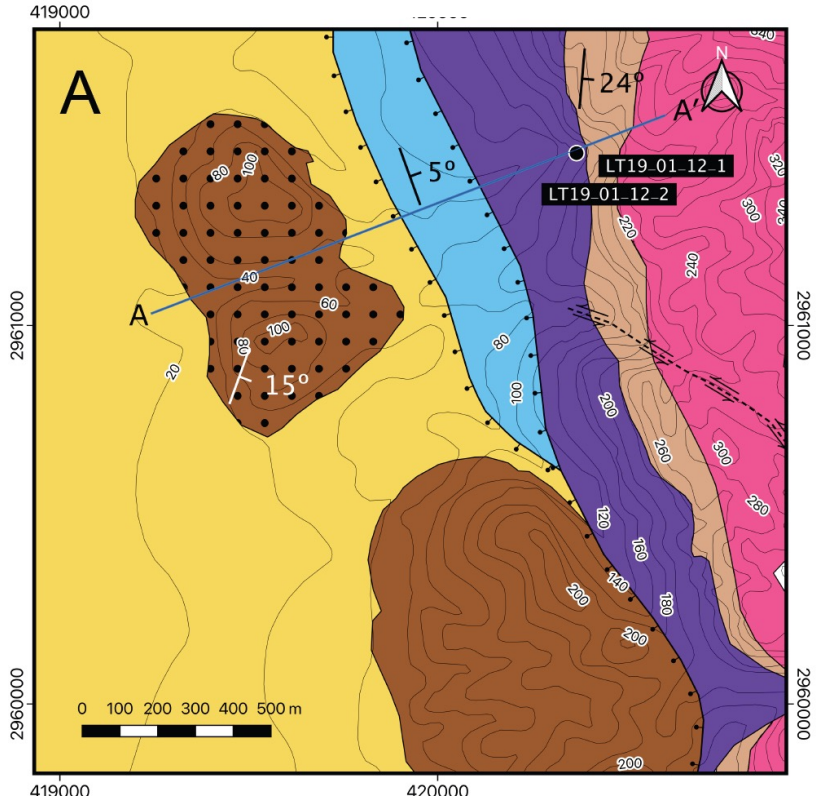
Busby and Putirka, 2025

Maps and cross sections at areas A and B:
Next slides.

Structural setting of the Concepción– Mulegé region, continued.







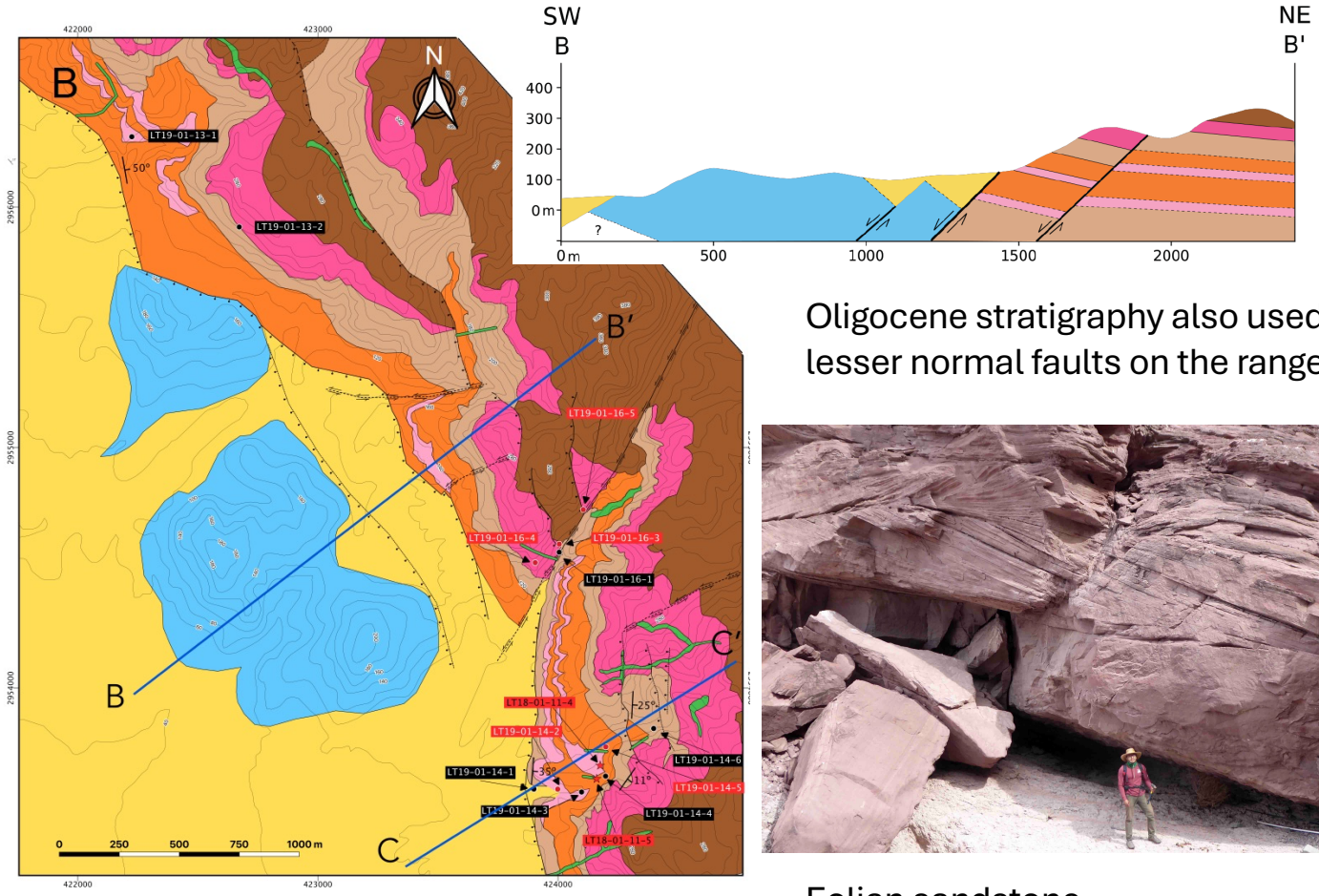
Cross section A – A':

Middle Miocene arc volcanic and volcaniclastic rocks (blue and brown)

dropped 2 km down against

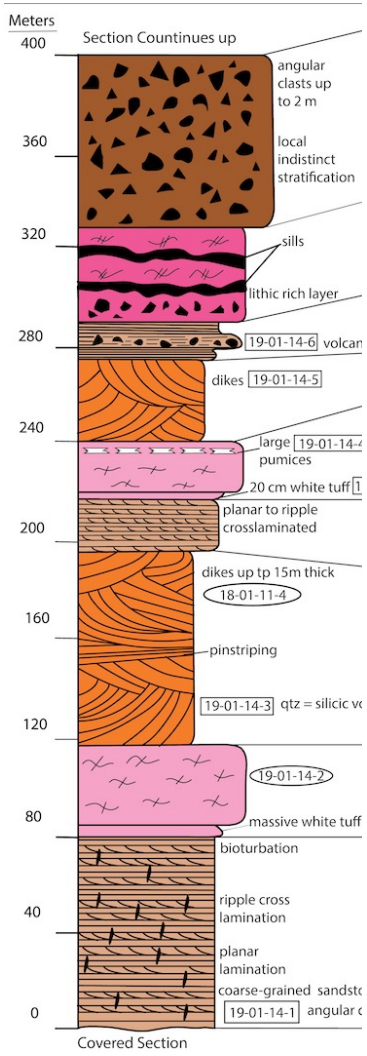
Early Cretaceous plutonic basement (purple).

Middle Miocene arc volcanic rocks (blue) dropped 1 km down against Oligocene forearc eolian (orange) fluvial (tan) and ignimbrites (pinks).



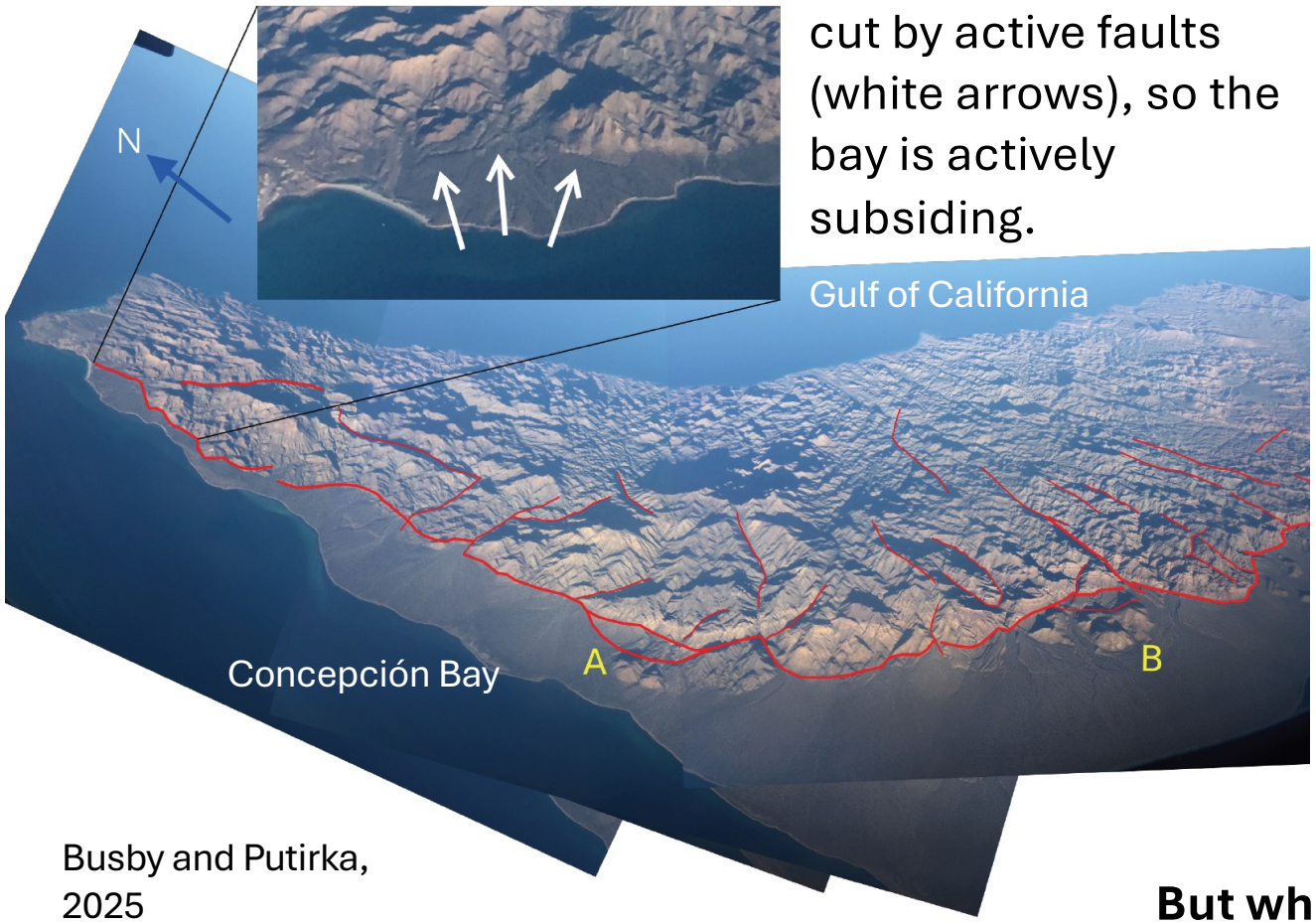
Oligocene stratigraphy also used to map lesser normal faults on the range front.

Eolian sandstone.



Structural setting of the Concepción– Mulege region, continued.

The alluvial fans are cut by active faults (white arrows), so the bay is actively subsiding.

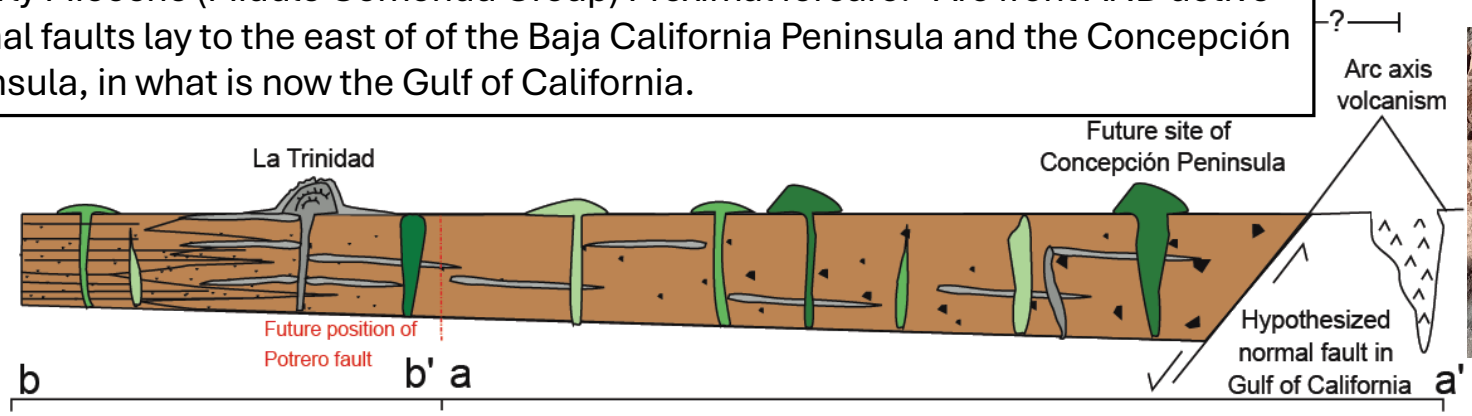


Busby and Putirka, 2025

Fault planes very well exposed, pure dip slip.

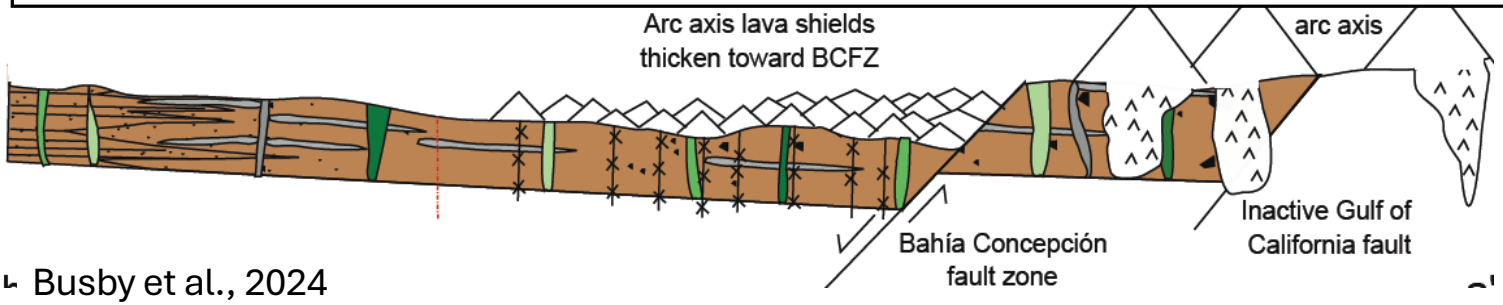
But when did extension begin???

1. Early Miocene (Middle Comondú Group) Proximal forearc: Arc front AND active normal faults lay to the east of of the Baja California Peninsula and the Concepción Peninsula, in what is now the Gulf of California.



Volcanic debris flow deposits.

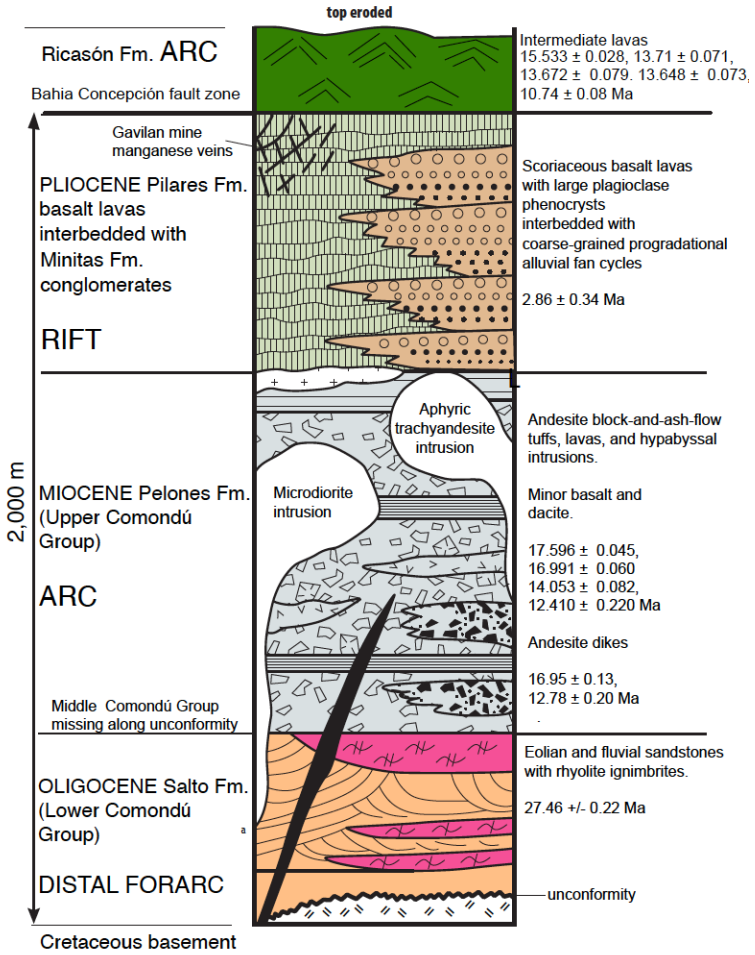
2. Middle Miocene (Upper Comondú Group): Arc volcanism and extension sweep westward into the Baja California Peninsula.
14 Ma arc lavas thicken dramatically toward toward the Bahía Concepción fault zone, indicating extension began by then (or perhaps earlier, see below).



↳ Busby et al., 2024

Lava flow breccias.

Northern Concepción Peninsula - formation names follow McFall, 1968; ages, tectonic setting and modern volcanological and geochemical names are ours.



Cretaceous granitic basement.

2B. Ricasón Formation: Upper Comondú Group **ARC** rocks (16-11 Ma) downdropped against granitic basement.

_____Bahia Concepción normal fault zone_____

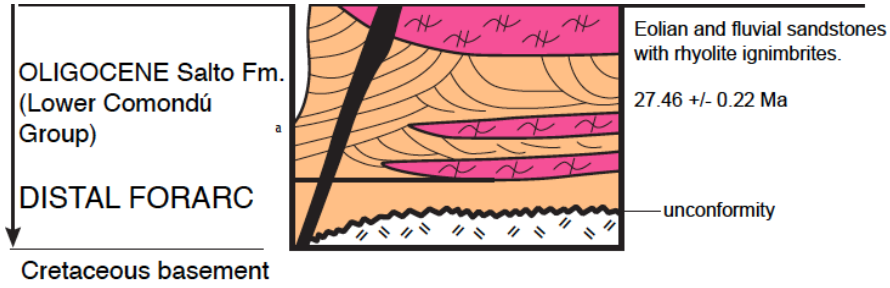
3. Pilares and Minares Formations **RIFT:**
Pliocene basalt lavas interfingering with coarse-grained alluvial fan deposits (3 Ma).

2A. Pelones Formation (Upper Comondú Group) **ARC**:
Middle Miocene andesite block-and-ash-flow tuffs, lavas and intrusions (18-12 Ma) and dikes (17-13 Ma).

Middle Comondú Group is missing here.

1. Salto Formation (Lower Comondú Group) **DISTAL FOREARC**: Oligocene distal ignimbrites and eolian-fluvial sandstones (27 Ma).

Northern Concepción Peninsula, continued.



1. Distal forearc (Oligocene, 27 Ma):

Salto Formation - predates Cenozoic tectonic and magmatic activity in Baja California.

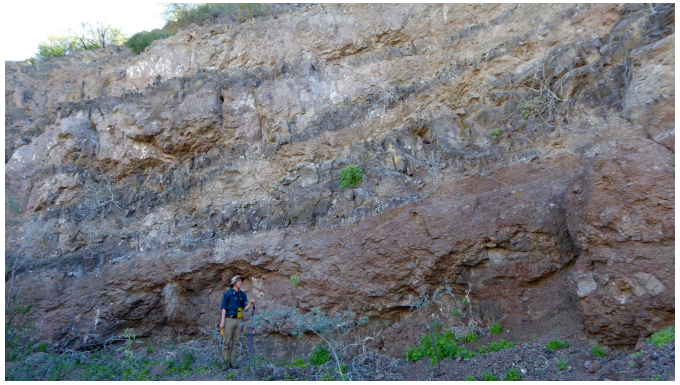
Map units are tabular and distinctive ignimbrite units form marker beds in the Bahía Concepción normal fault zone.

Student Quinton Mindrup standing on normal fault that drops upper part of Salto Formation down against lower part of Salto Formation.

Northern Concepción Peninsula, continued.

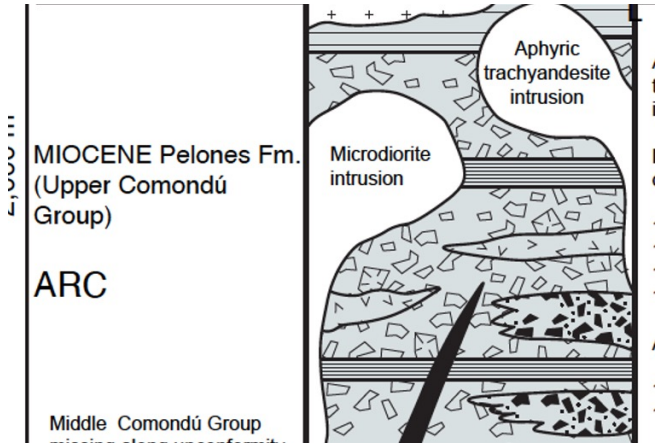
2. Arc andesite volcanic rocks and intrusions.

2A Pelones Formation - on footwall of Bahia Concepción fault. These are syn-subduction (18 – 12 Ma).



Dominated by block-and-ash-flow tuffs

with lesser lavas.



Large intrusions and abundant dikes.

Northern Concepción Peninsula, continued.

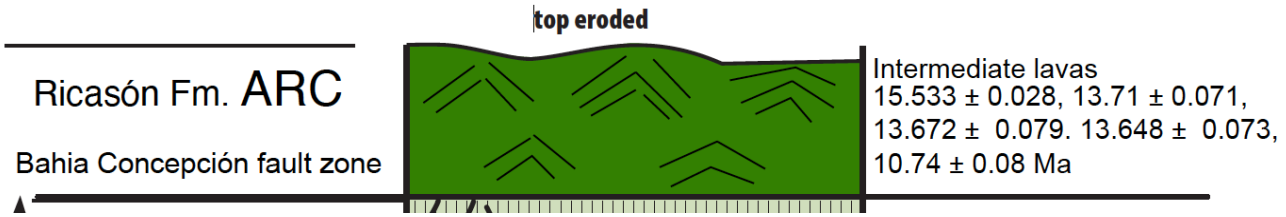
2. Arc andesite volcanic rocks and intrusions, continued.

2B. Ricasón Formation on hanging wall of Bahia Concepción fault (16 – 11 Ma). Also syn-subduction.

Is entirely lavas.

This contrasts with the Pelones Formation arc volcanic rocks on the footwall of the Bahia Concepción fault, which are the same age (18 – 12 Ma) and are mostly block-and-ash-flow tuffs.

This suggests that the two formations were deposited in separate basins, perhaps indicating that **extension began by 18 Ma.**

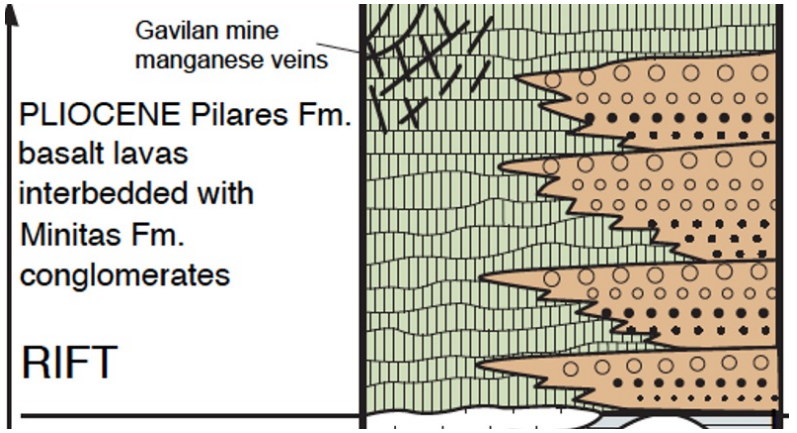


Primary dip on lavas in a lava shield.

Northern Concepción Peninsula, continued.

3. Pilares and Minares Formations **RIFT:**

Pliocene basalt lavas interfingering with coarse-grained alluvial fan deposits (3 Ma).

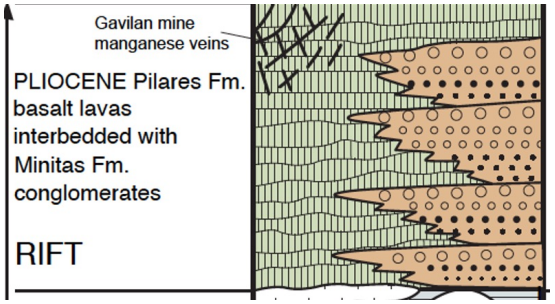


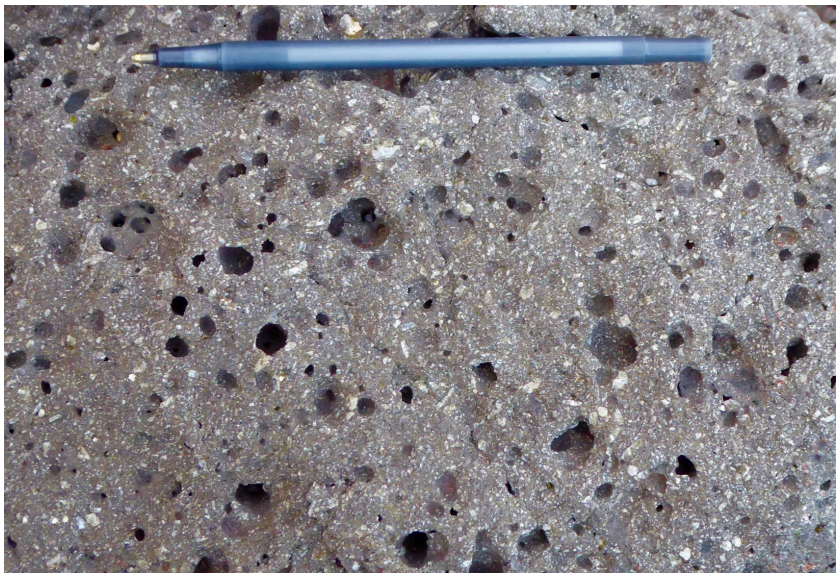
Basalt lavas.

Coarse-grained volcanic lithic conglomerates.

Northern Concepción Peninsula, continued.

3. Pilares Formation **RIFT** basalts (Pliocene, 3 Ma).



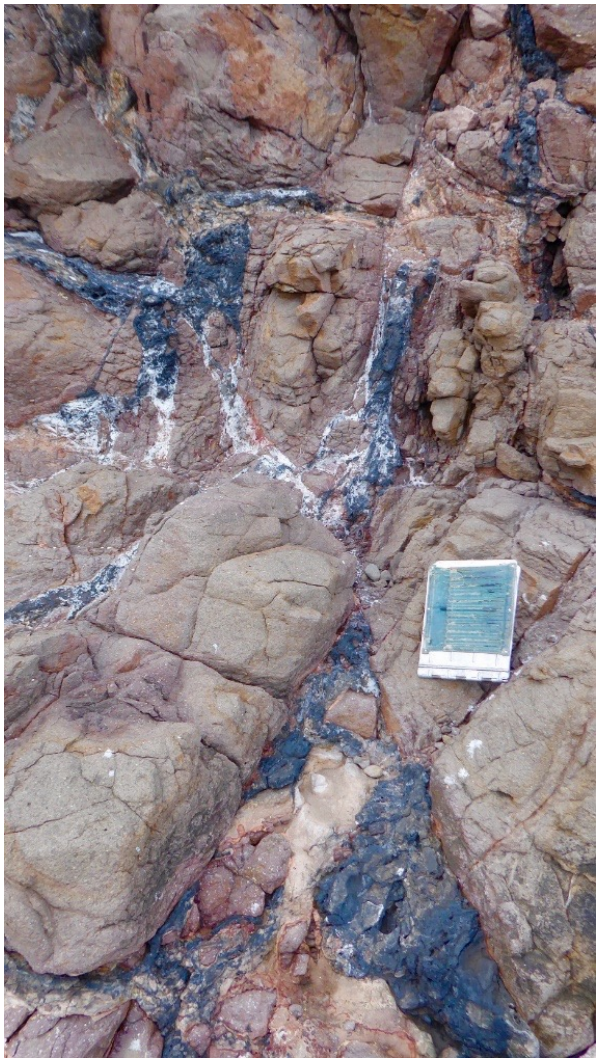


Section of glassy plagioclase-rich basalt lavas, up to 300 m thick.

PONDED IN A BASIN.

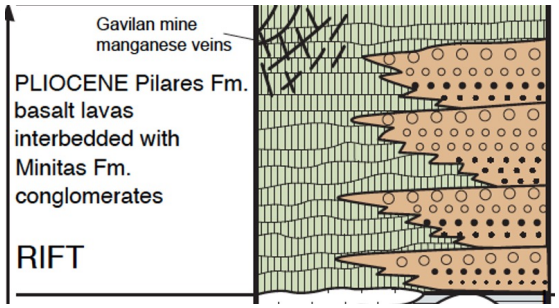
Locally contains abundant manganese oxide NW-SE veins: Gavilán Mine.

(see references in Camprubi et al., 2007).

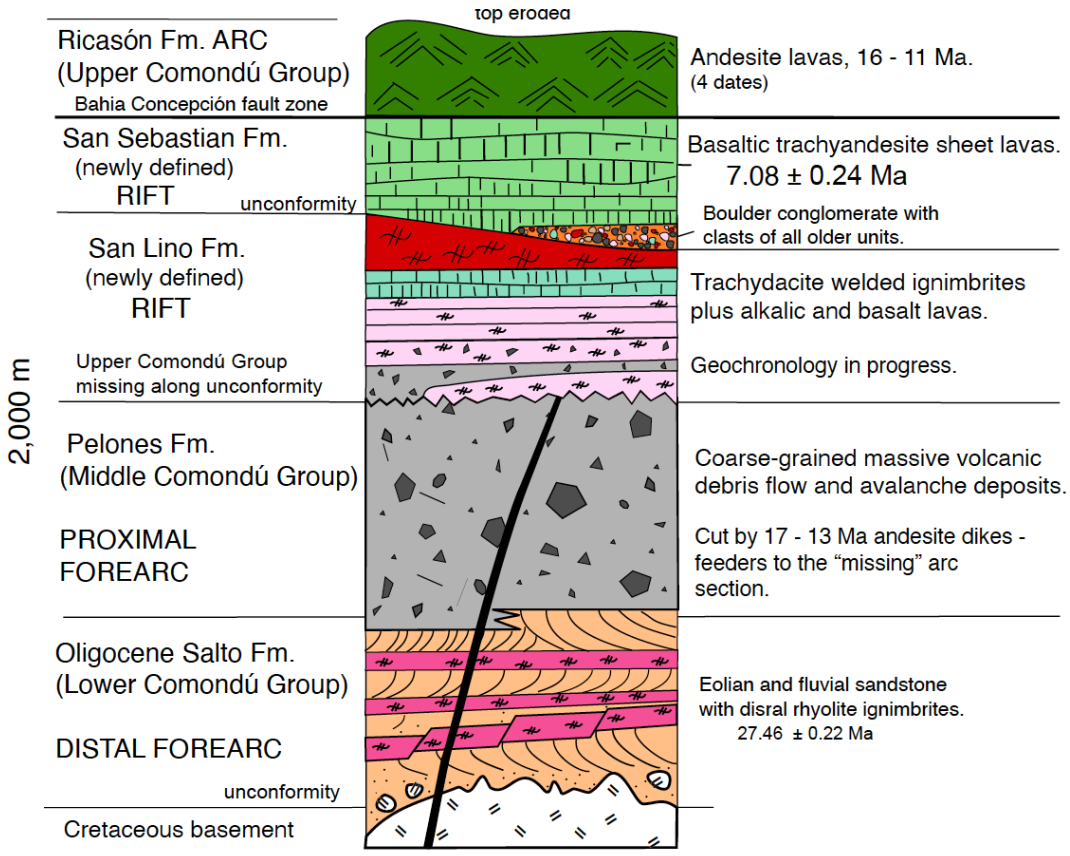


Northern Concepción Peninsula, continued.

3. Minitas Formation coarse-grained volcanic lithic conglomerates and sandstones interfinger with the rift basalts in progradational alluvial fan cycles .



The Southern Concepción Peninsula



The southern Concepción Peninsula differs from the northern peninsula in the following ways:

The Pliocene-Late Miocene rift volcanic section is thicker, and the Middle Miocene Upper Comondú Group arc volcanic section that should lie below it is absent.

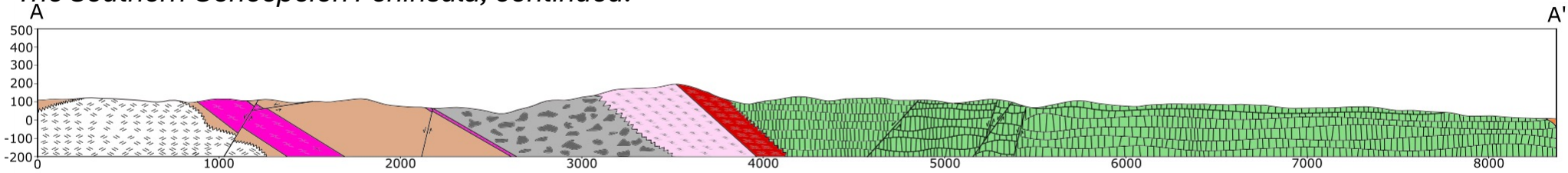
We infer that this is due to erosion along an **unconformity at the base of** the rift rocks.

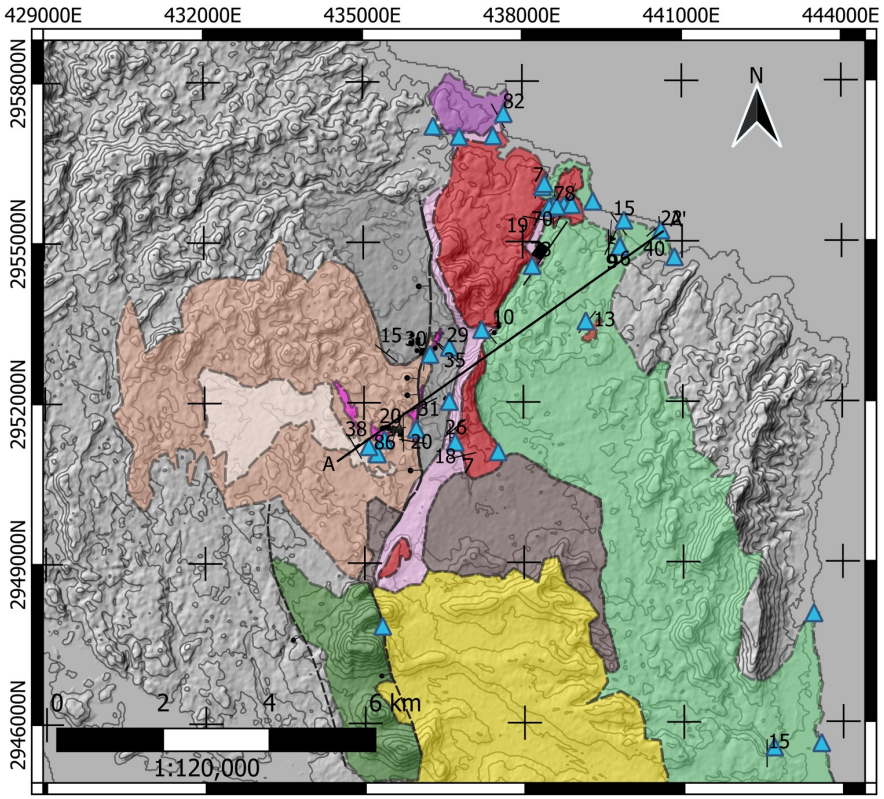
The "Pelones Formation" of McFall here consists of Early Miocene Middle Comondú Group volcanic debris flow – avalanche deposits, NOT Middle Miocene arc volcanic rocks, as it is in the north. One of them needs to be renamed.

We infer that the Middle Comondu Group is absent in the north due to erosion along an **unconformity at the base of the arc rocks.**

Erosional unconformities are common in subaerial volcanic terranes, particularly in tectonically active settings, and form mappable surfaces. Future mapping and sampling is needed to trace these unconformities across the central peninsula.

The Southern Concepción Peninsula, continued.

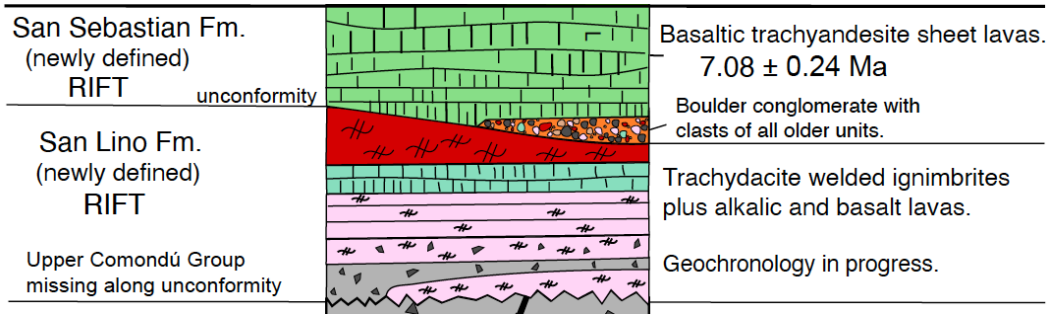




Angular unconformities also occur within the rift volcanic section, as expected:

Rift ignimbrites (red and pink) overlain in angular unconformity by rift lavas (greens,

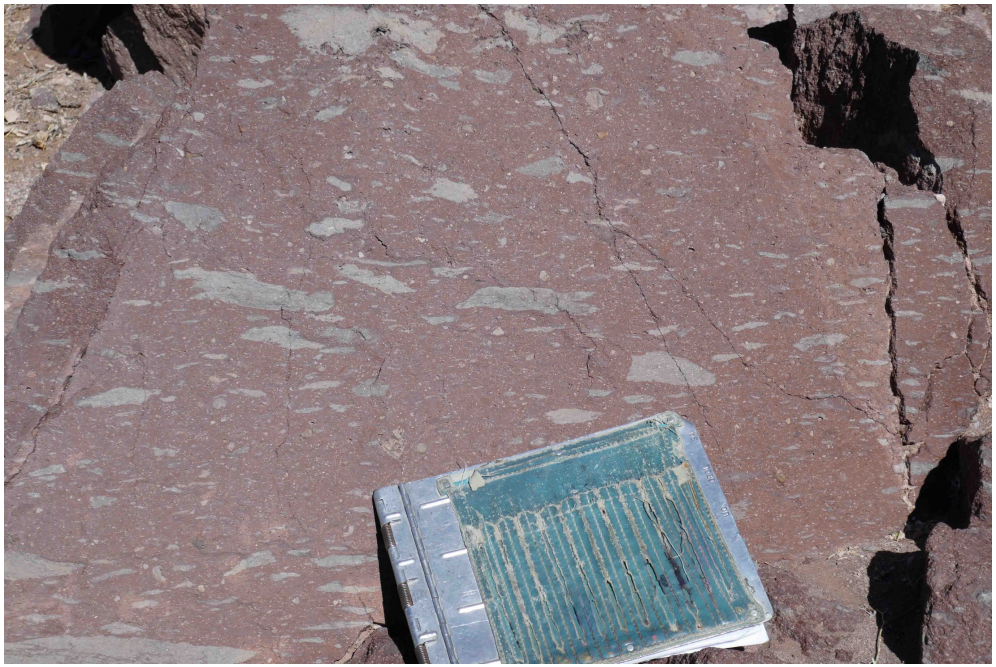
The Southern Concepción Peninsula, continued.



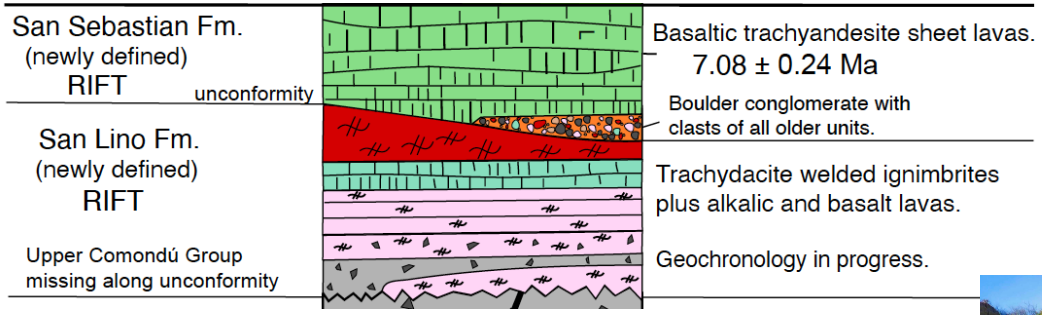
Newly-defined rift volcanic formations (divided out of McFall's Pelones Formation):

San Lino Formation welded ignimbrites, plus basalt and basaltic trachyandesite lavas.

Geochronology in progress.



The Southern Concepción Peninsula, continued.



San Sebastian Fm. rift lavas.

Newly-defined rift volcanic formations (divided out of McFall's Pelones Formation), continued:

San Sebastian Formation basaltic trachyandesite sheet lavas, 7 Ma.

These are cut by a rift ignimbrite vent with vertical welding fabrics (geochronology in progress).

Red ignimbrite vent with vertical welding fabric, crosscutting tan debris flow deposits.

CONCLUSIONS

In this talk we distinguish between arc and rift volcanic rocks by age and lithology:

Arc: 18-12 Ma (synsubduction) andesite lavas, block-and-ash-flow tuffs, dikes and hypbyssal intrusons.

Rift: <12 Ma (post-subduction) bimodal volcanic rocks, including welded silicic ignimbrites and mafic lavas.

IN THE NEXT TALK, KEITH PUTIRKA WILL SHOW THE GEOCHEMISTRY TO SUPPORT THIS.

The upshot: this is an excellent place to study THE ARC-RIFT TRANSITION.