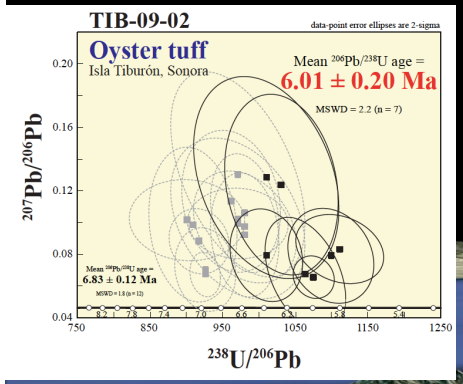
Volcanic Rocks and Microfossils Confirm a Late Miocene age for Marine Strata on Isla Tiburón, Gulf of California



Scott Bennett [1] Mike Oskin [1]

Rebecca Dorsey [2] Alexander Iriondo [3]

1 - Univ. of California, Davis

2 - Univ. of Oregon

3 - UNAM Juriquilla

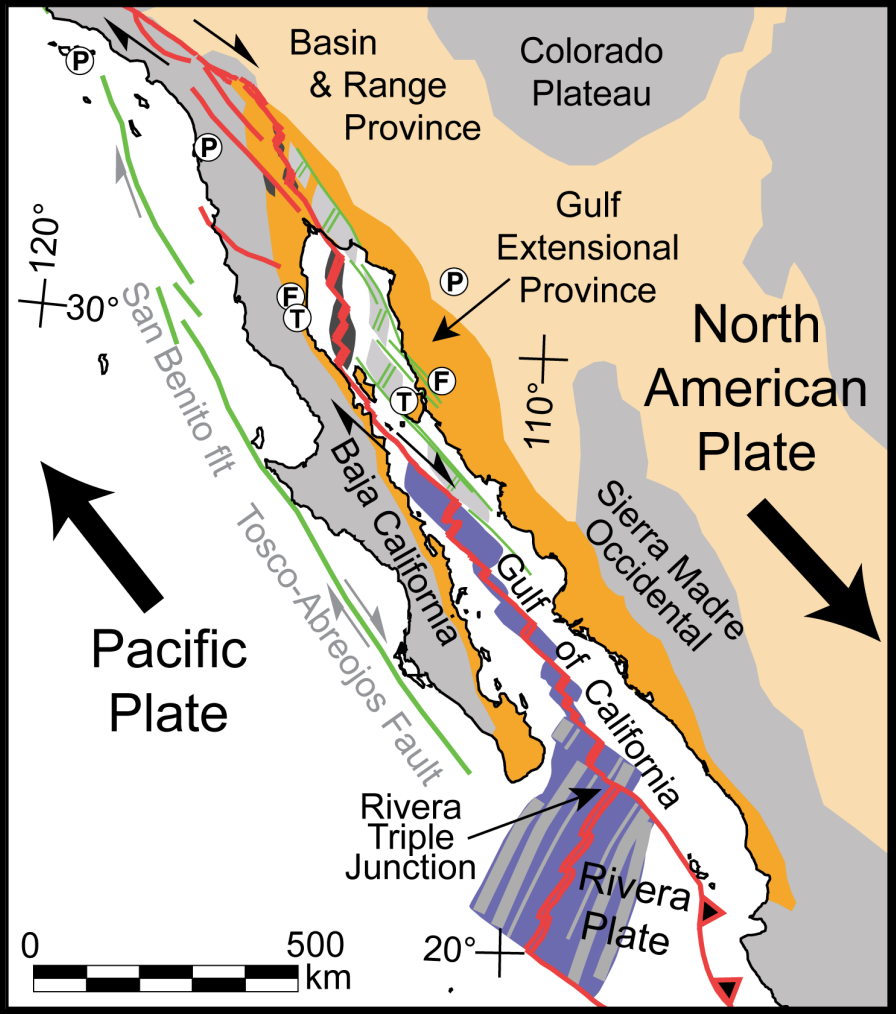
Paper 15 - 4

GSA Cordilleran Section Meeting

Queretaro, Mexico

April 29, 2012

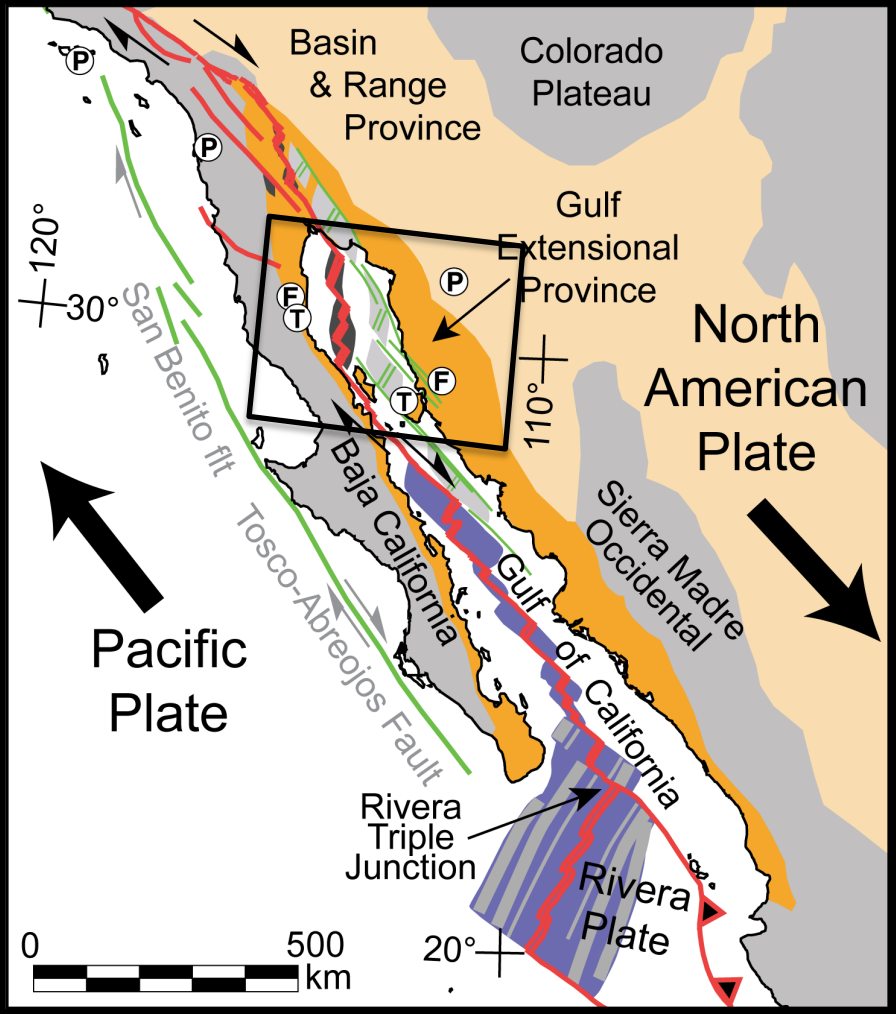
Implications of Incipient Gulf Seaway



Oskin & Stock (2003), Arregón-Arreola & Martín-Barajas (2007), Fletcher et al. (2007)

- paleogeography
- evolution biology
- models of 4D plate boundary strain evolution
- geodynamic setting of rifting

Implications of Incipient Gulf Seaway



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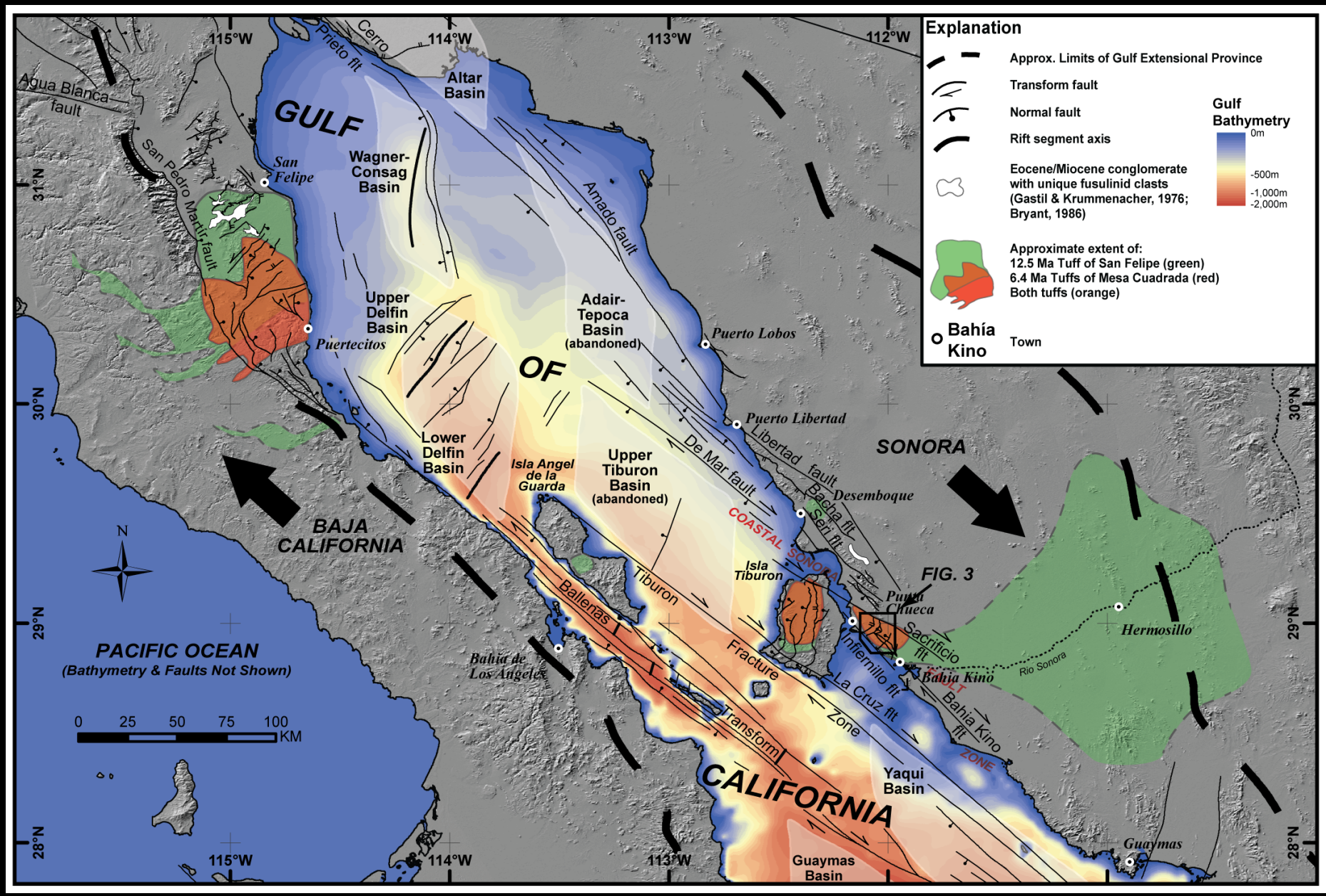
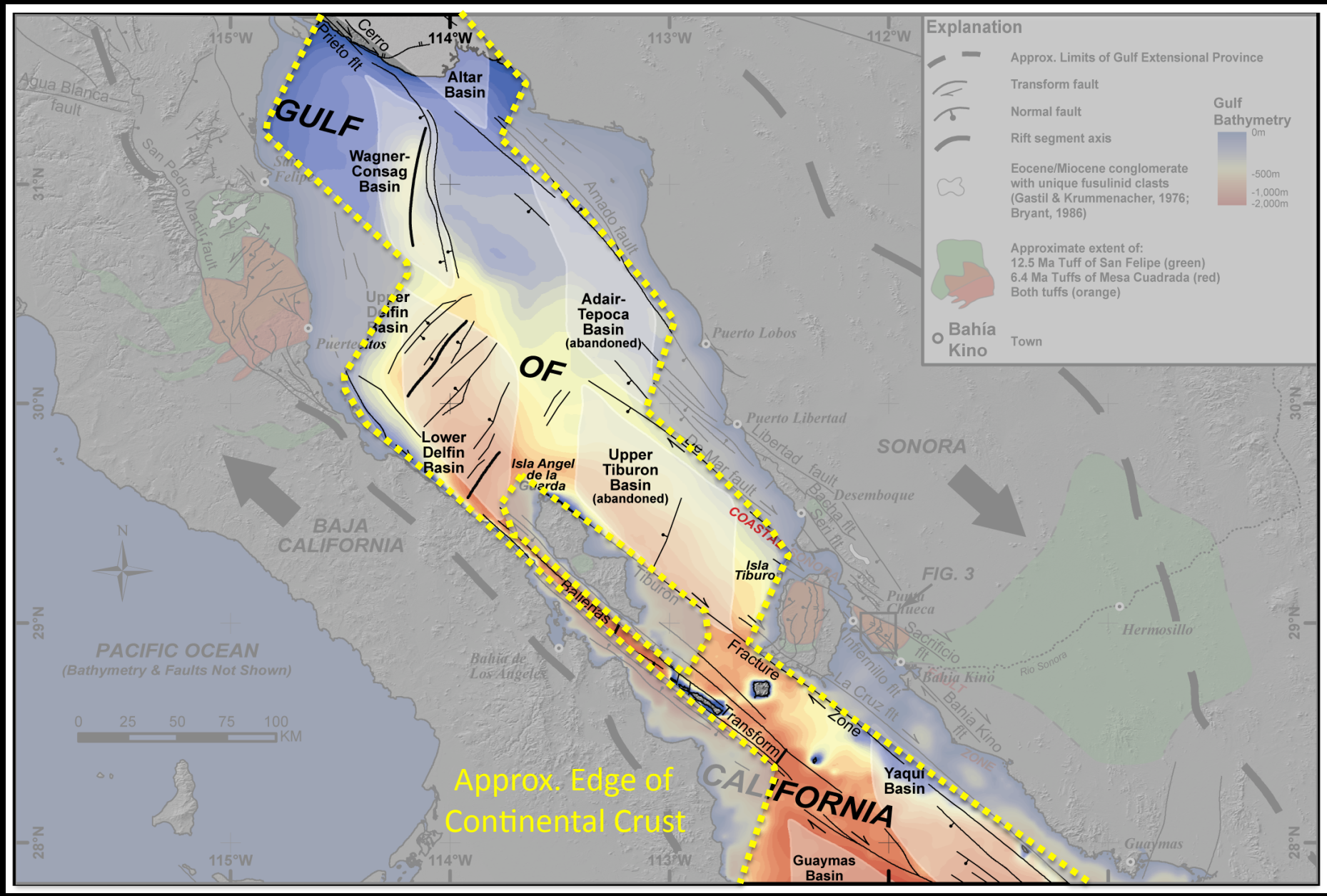
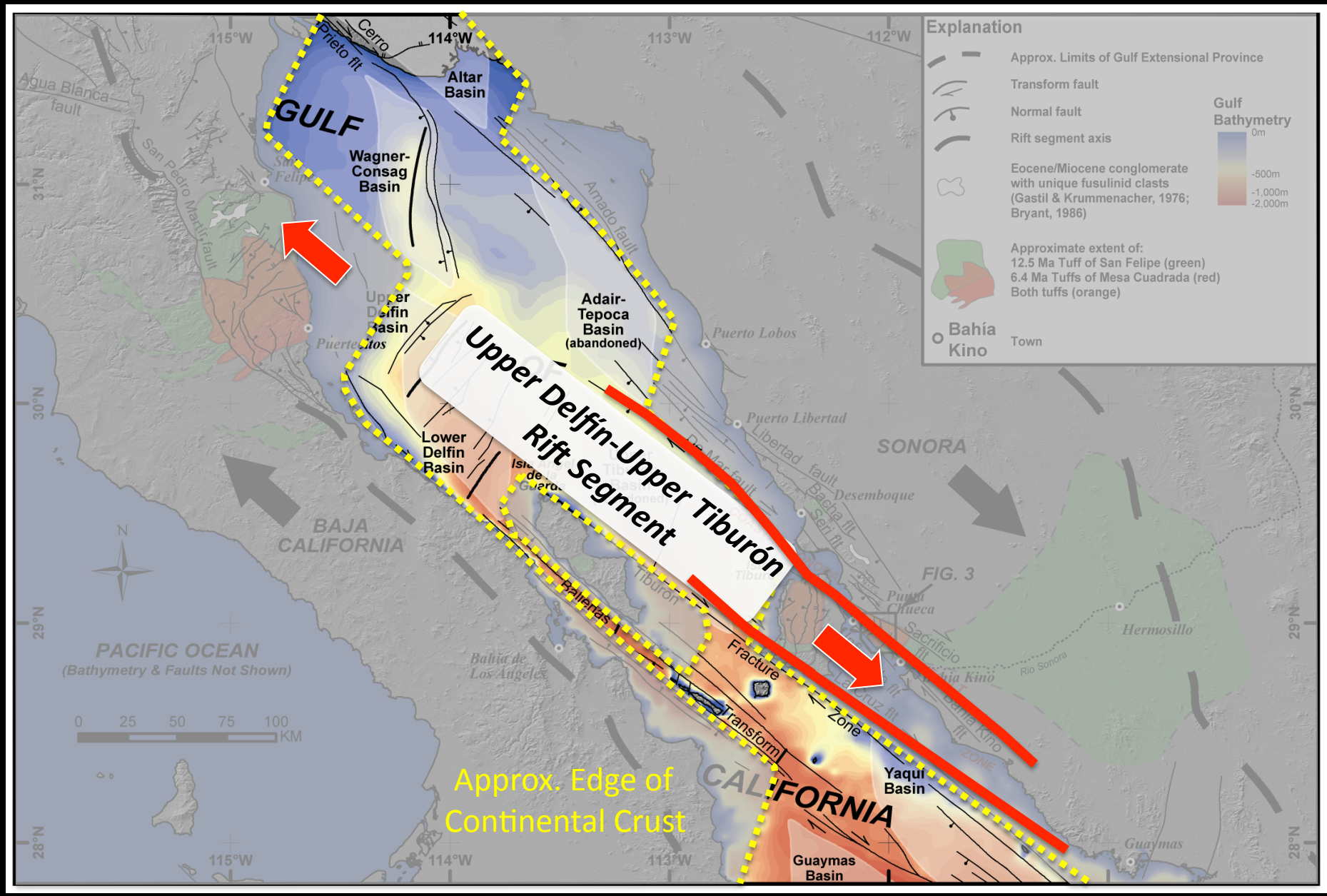
Northern Gulf of California



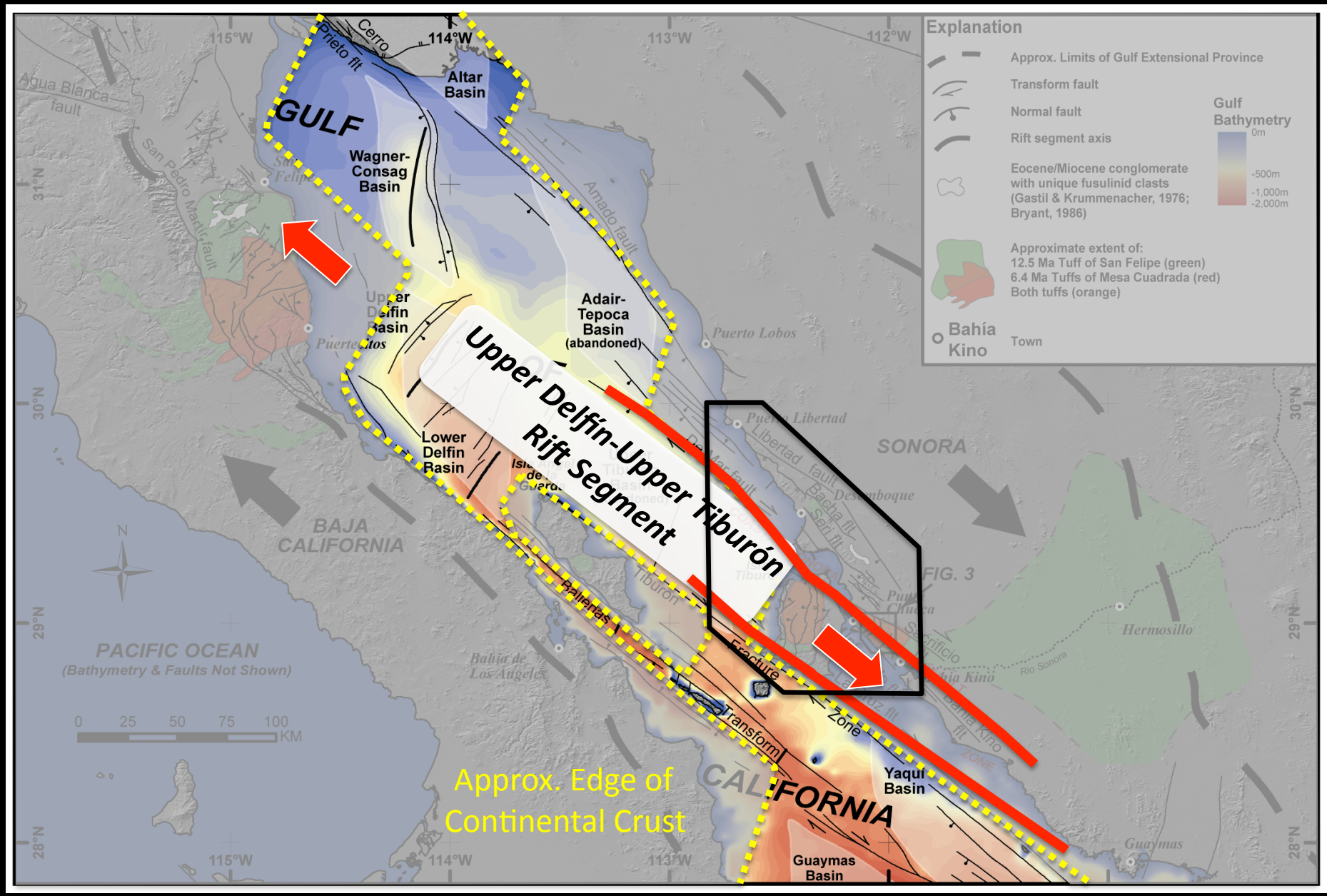
Northern Gulf of California



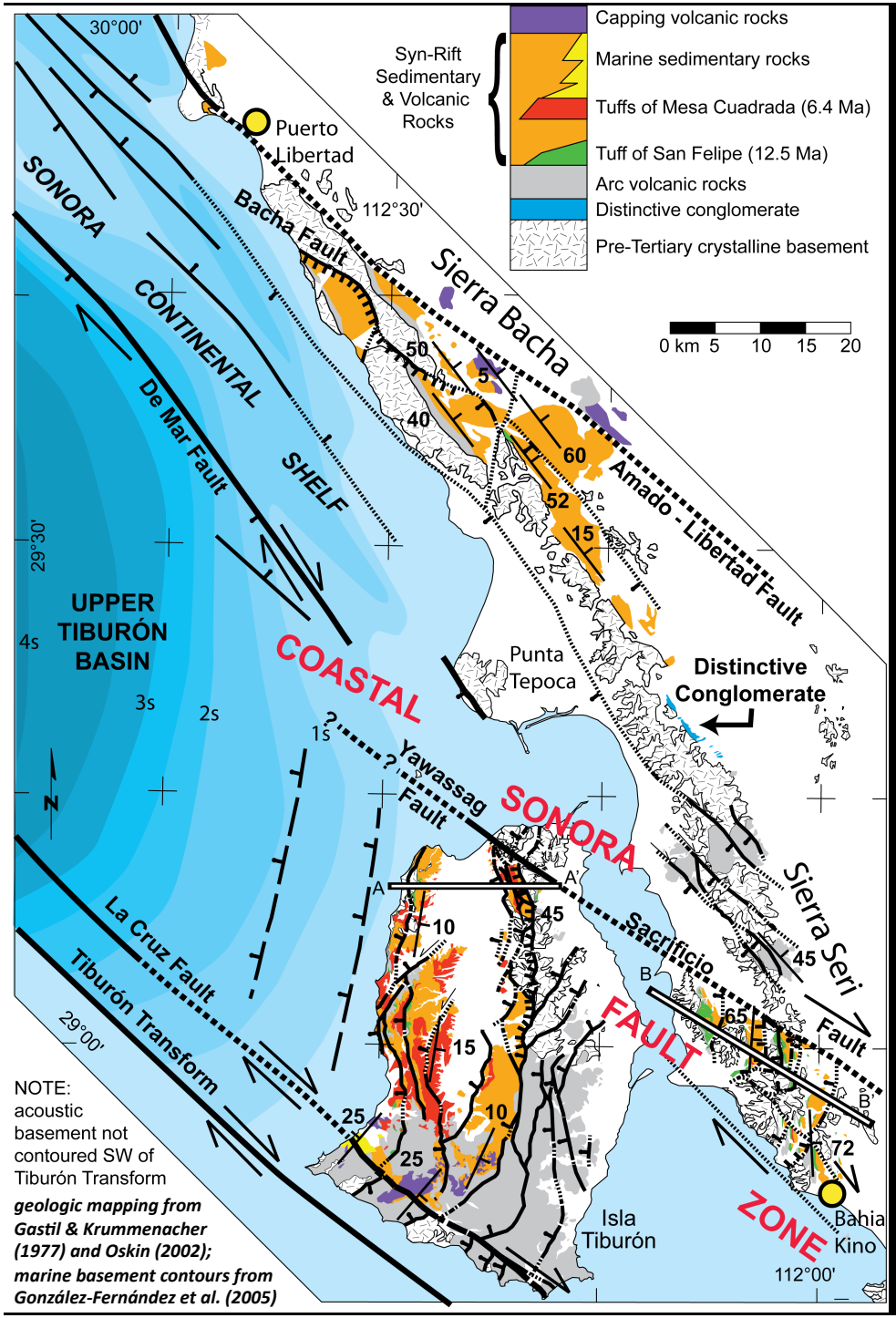
Northern Gulf of California



Northern Gulf of California

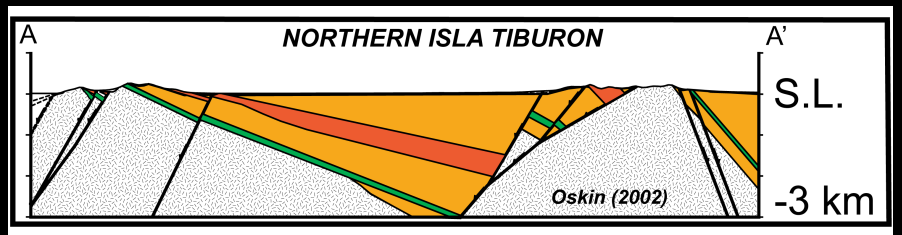


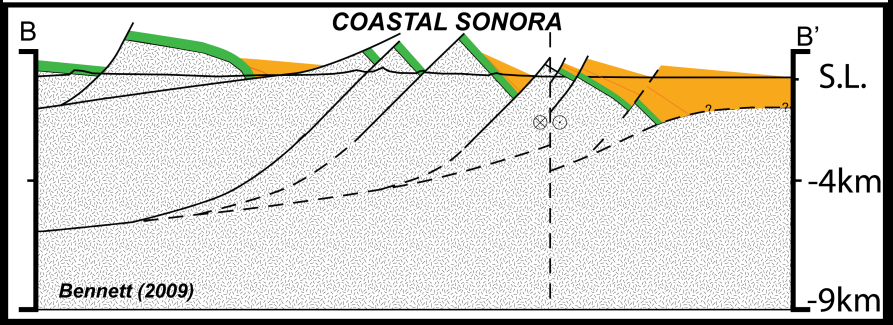
Regional Geology



NOTE: acoustic basement not contoured SW of Tiburón Transform

geologic mapping from Gastil & Krummenacher (1977) and Oskin (2002); marine basement contours from González-Fernández et al. (2005)





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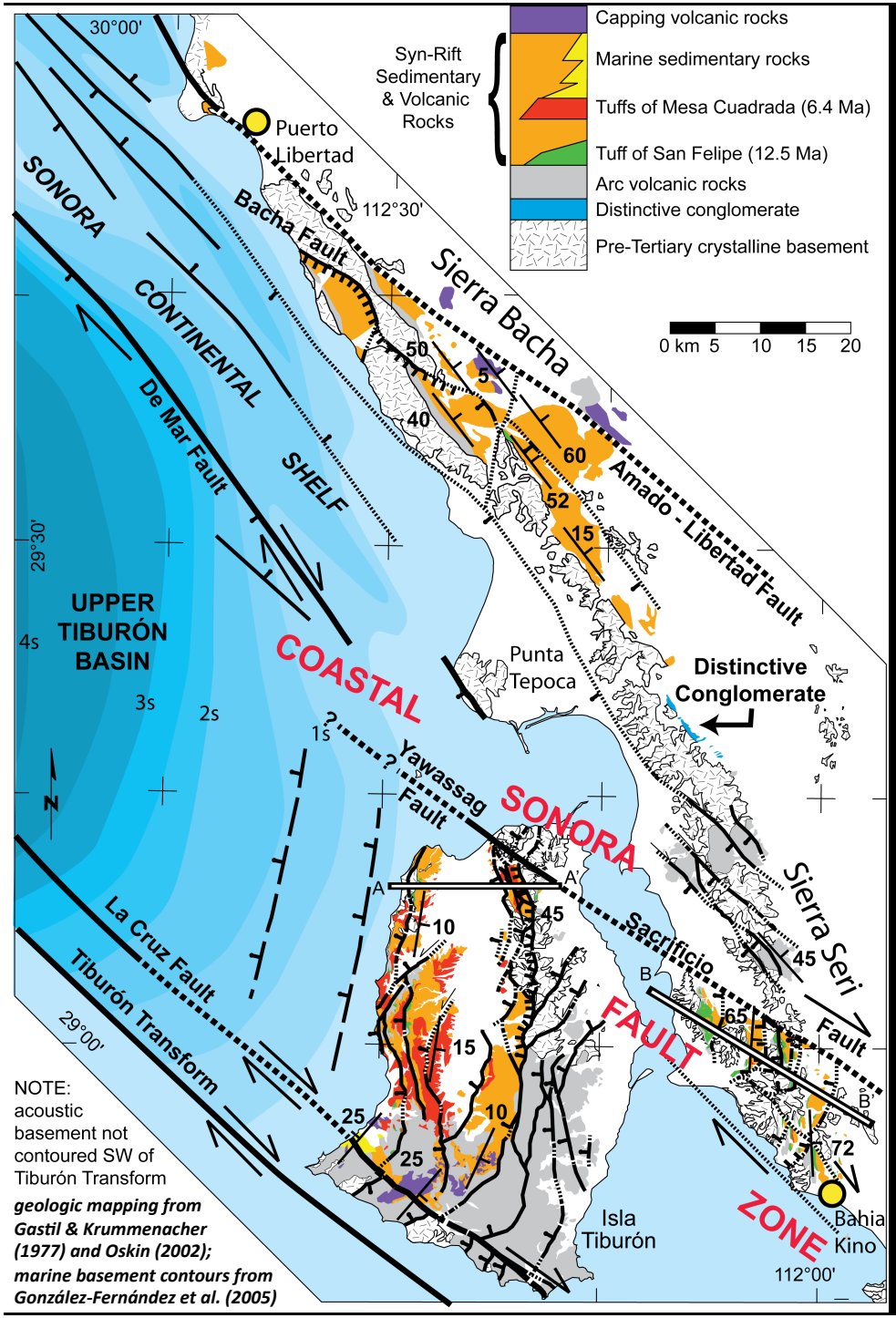

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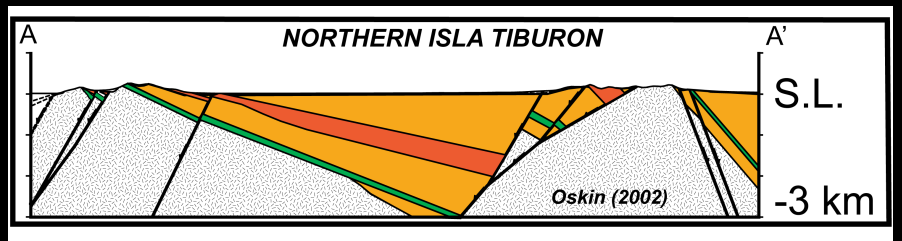
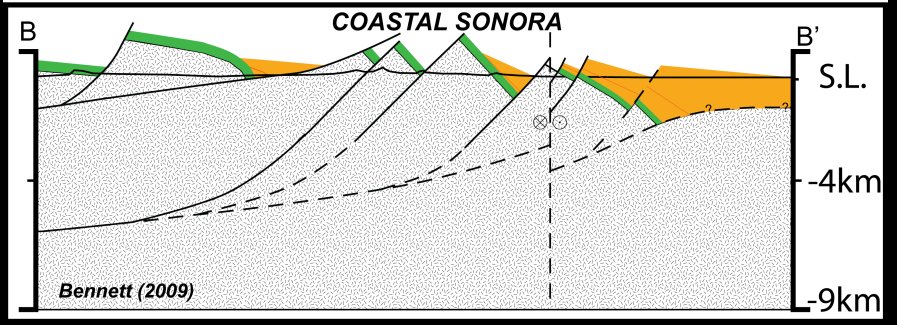




<u>1:10,000-scale Mapping</u>

- 60-cm Quickbird satellite imagery

<u>Syn-rift sedimentary basins</u>

- basin-filling sequences

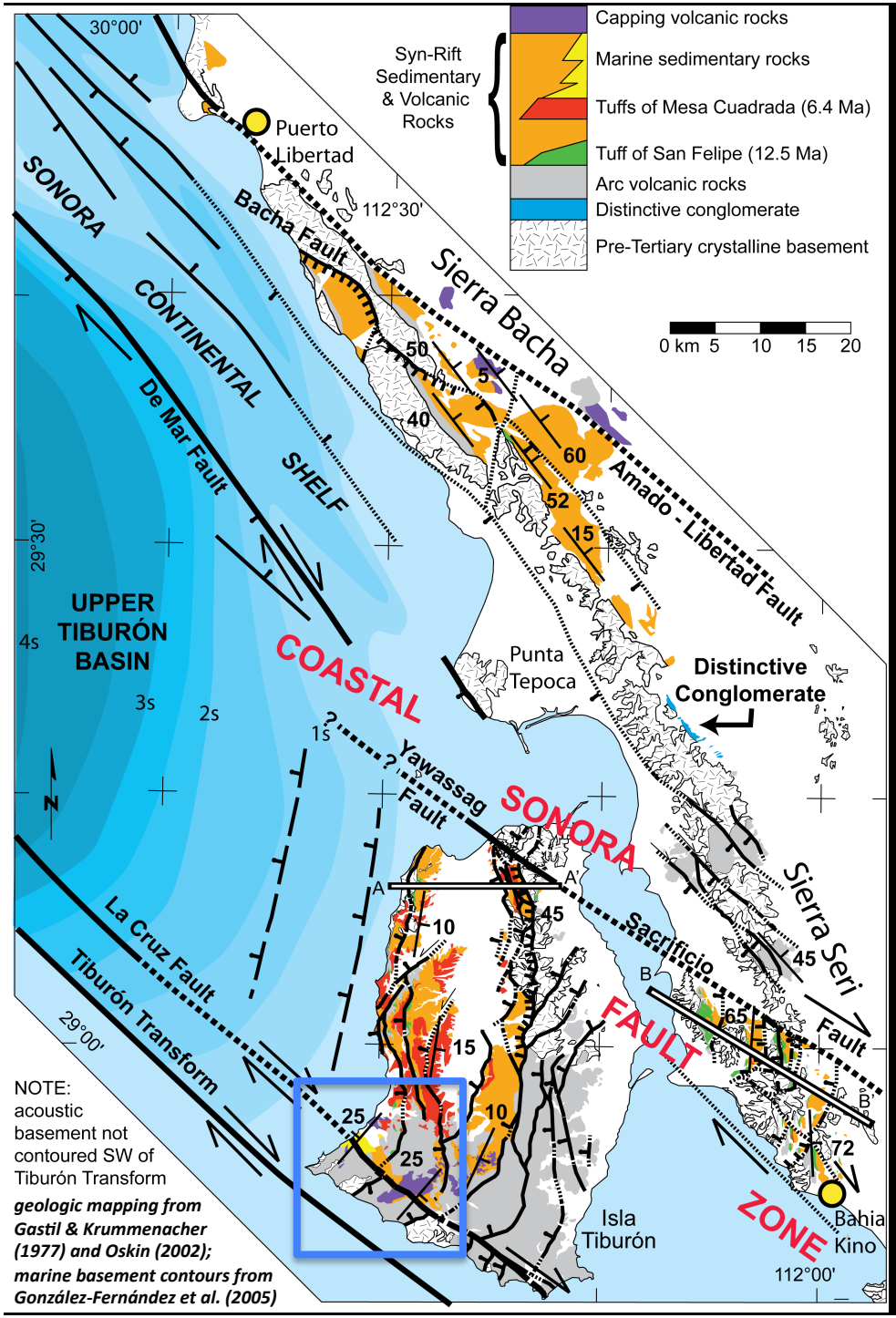
<u>Structural analysis</u>

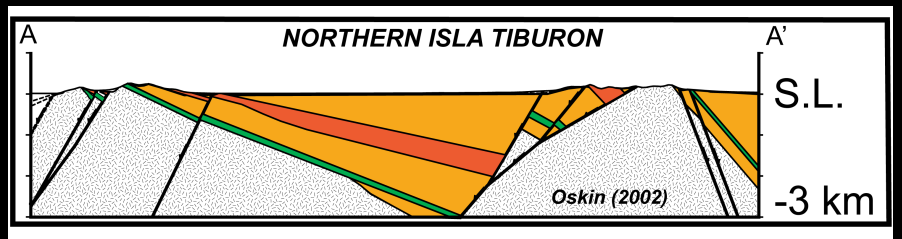
- brittle faults & folds

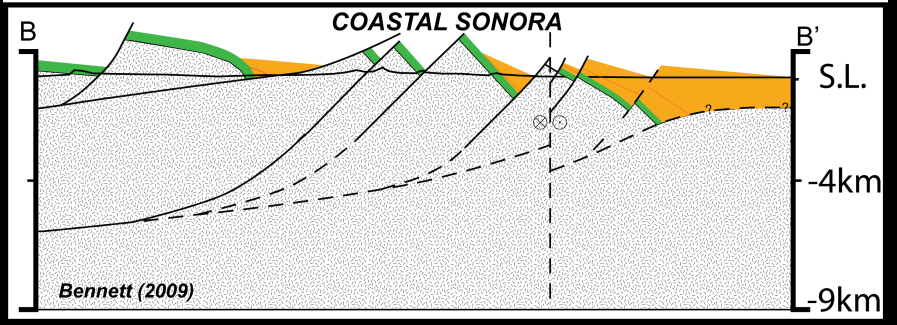
<u>Geochronology of Basins</u>

- underlying, interbedded, & overlying volcanic rocks

Regional Geology







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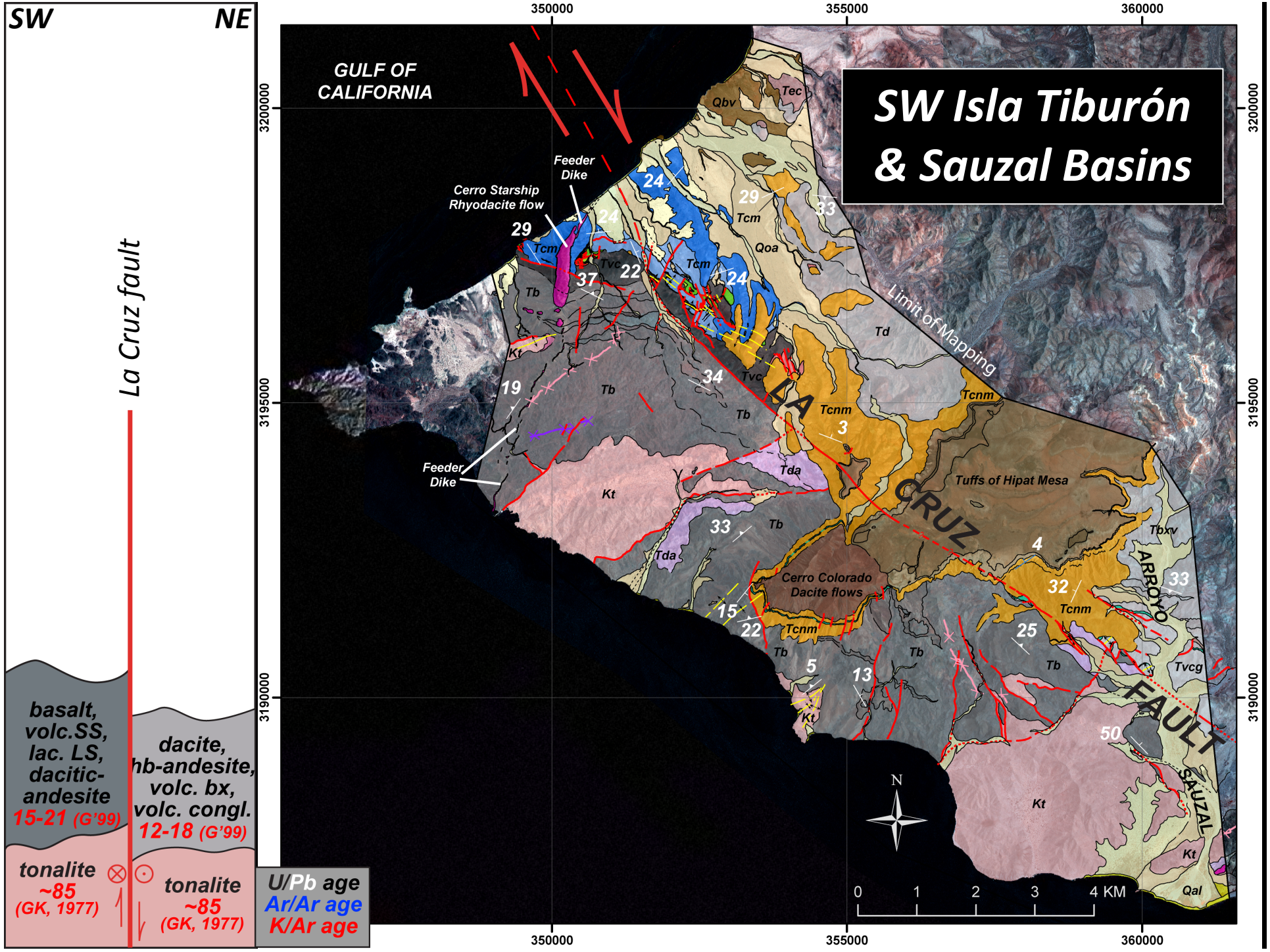
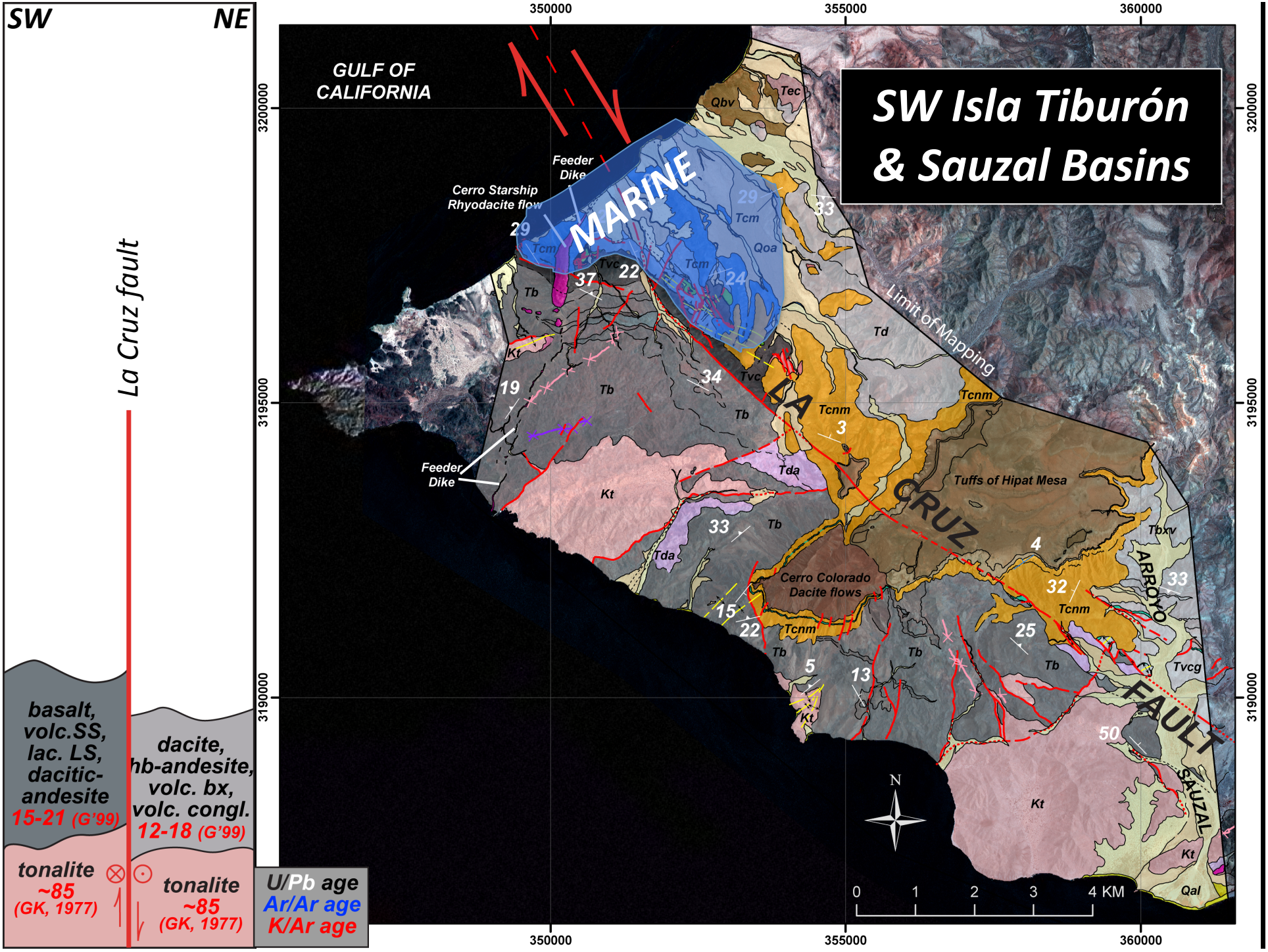
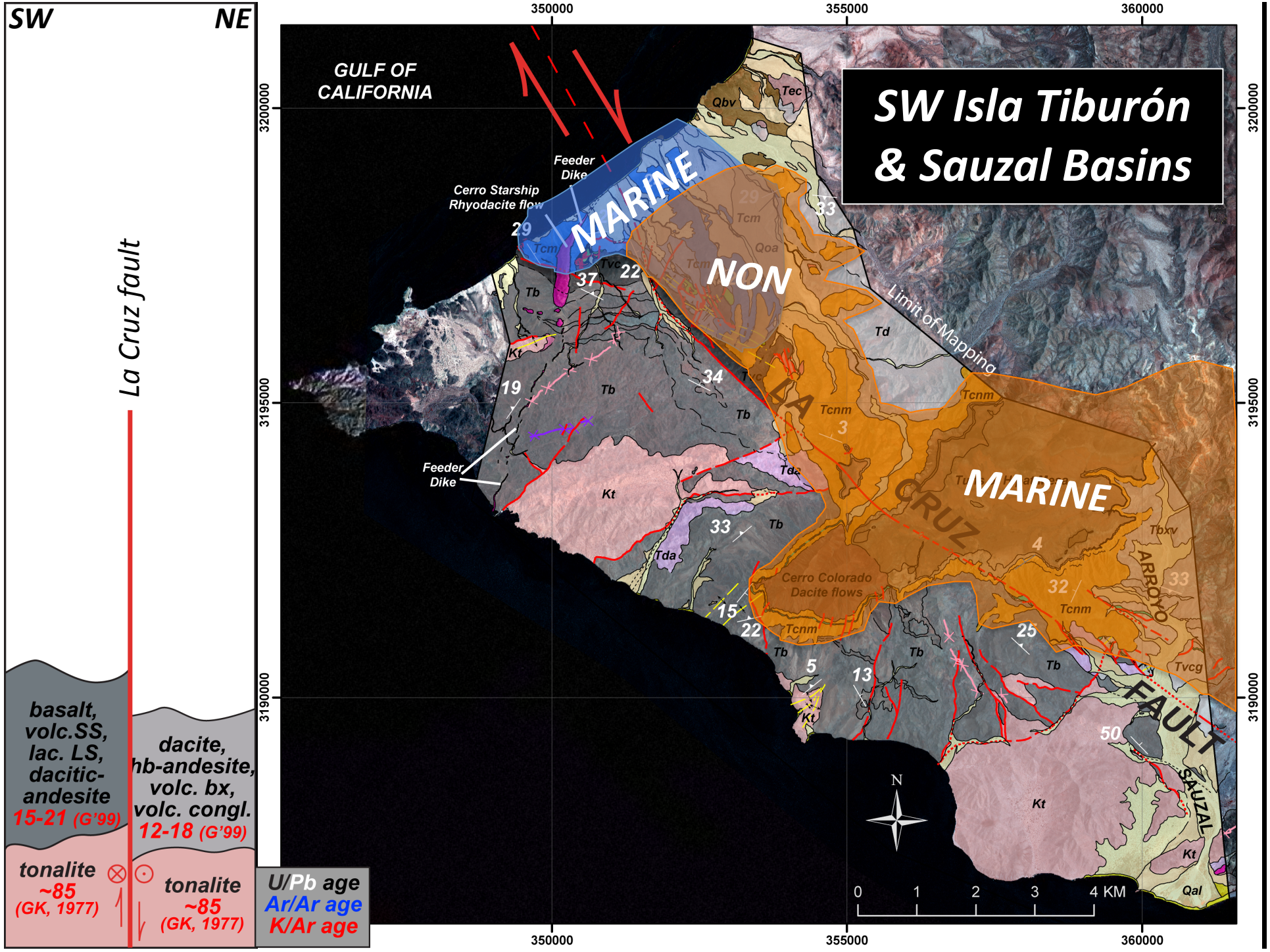
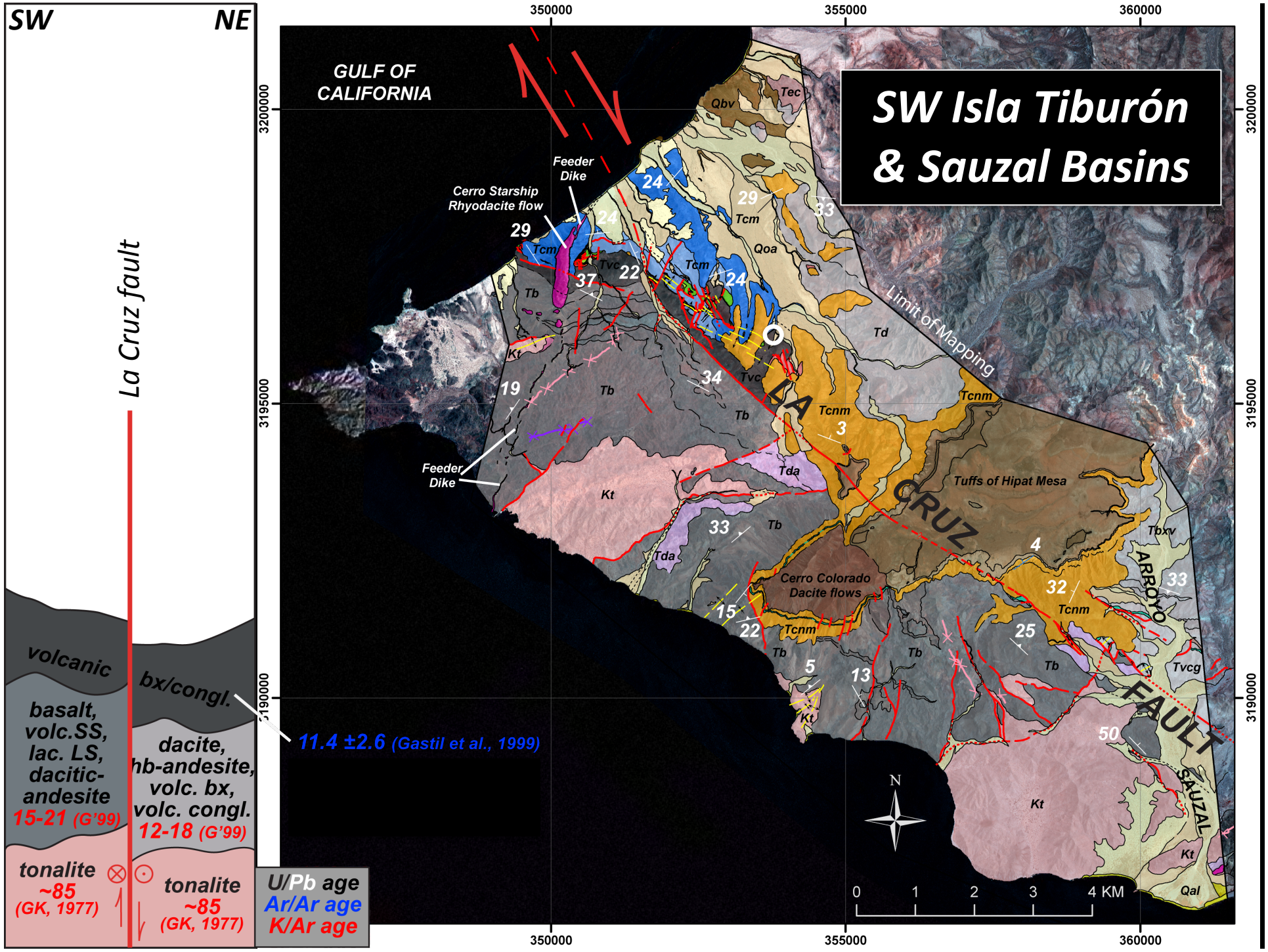
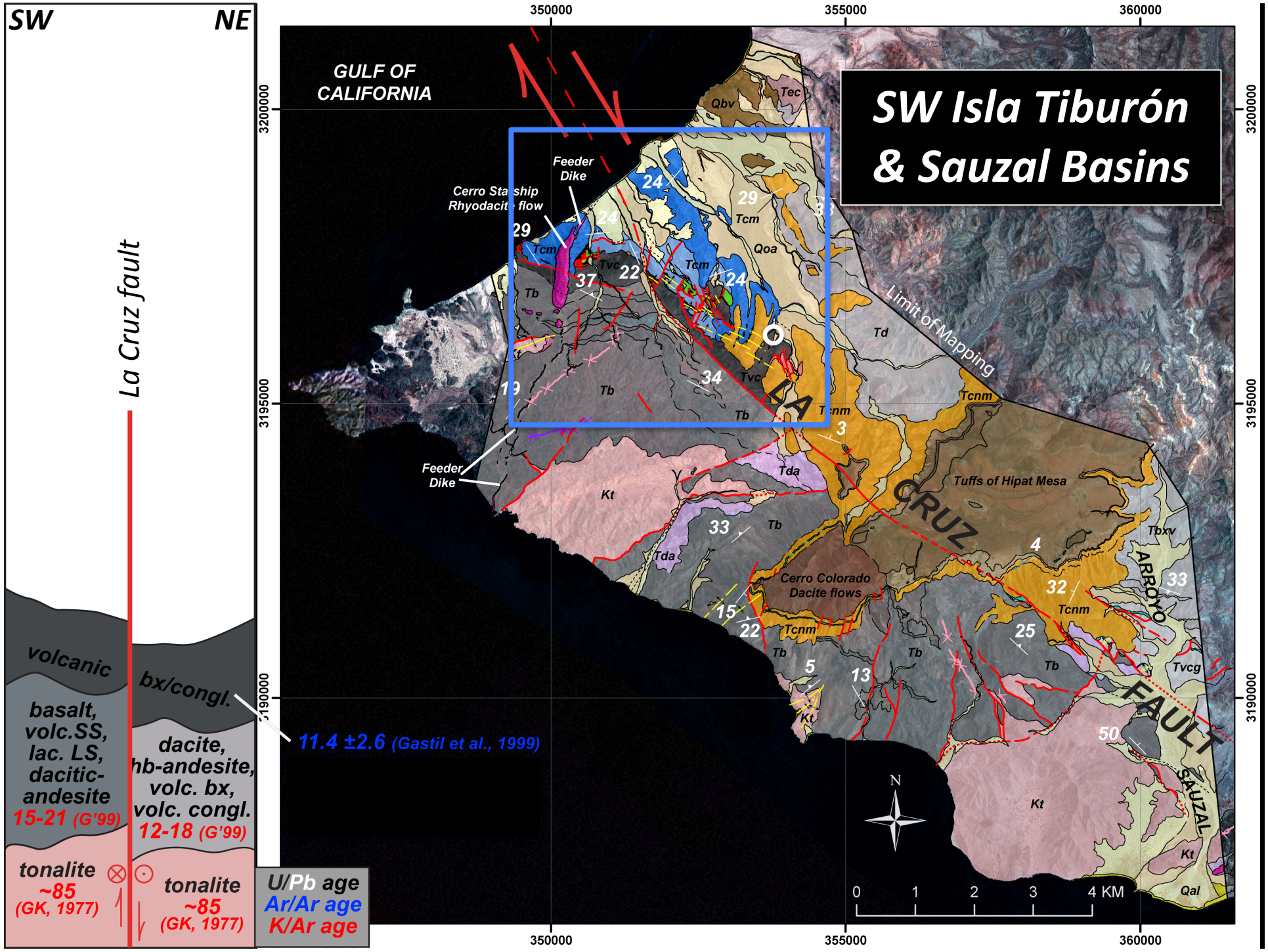

SW
NE
La Cruz fault
basalt, volc.SS, lac. LS, dacitic-andesite
15-21 (G'99)
dacite, hb-andesite, volc. bx, volc. congl.
12-18 (G'99)
tonalite ~85 (GK, 1977)
tonalite ~85 (GK, 1977)
U/Pb age
Ar/Ar age
K/Ar age
350000
355000
360000
3200000
3195000
3190000
GULF OF CALIFORNIA
SW Isla Tiburón & Sauzal Basins
Feeder Dike
Cerro Starship Rhyodacite flow
Feeder Dike
Limit of Mapping
LA CRUZ FAULT
ARROYO SAUZAL
Tuffs of Hipat Mesa
Cerro Colorado Dacite flows
Qbv
Tec
Tcm
Qoa
Td
Tvc
Tb
Tcnm
Tda
Kt
Tbxv
Tvcg
Qal
N
0 1 2 3 4 KM



SW Isla Tiburón & Sauzal Basins


SW
NE
La Cruz fault
basalt, volc.SS, lac. LS, dacitic-andesite
15-21 (G'99)
dacite, hb-andesite, volc. bx, volc. congl.
12-18 (G'99)
tonalite ~85 (GK, 1977)
tonalite ~85 (GK, 1977)
U/Pb age
Ar/Ar age
K/Ar age
350000
355000
360000
3200000
3195000
3190000
GULF OF CALIFORNIA
SW Isla Tiburón & Sauzal Basins
MARINE
NON
LA CRUZ
MARINE
FAULT
SAUZAL
ARROYO
Feeder Dike
Cerro Starship Rhyodacite flow
Limit of Mapping
Cerro Colorado Dacite flows
Qbv
Tec
Tcm
Qoa
Tvc
Tb
Kt
Td
Tcnm
Tda
Tbxv
Tvcg
Qal
N
0 1 2 3 4 KM


SW
NE
La Cruz fault
volcanic
bx/congl.
basalt, volc.SS, lac. LS, dacitic-andesite
15-21 (G'99)
dacite, hb-andesite, volc. bx, volc. congl.
12-18 (G'99)
tonalite ~85 (GK, 1977)
tonalite ~85 (GK, 1977)
U/Pb age
Ar/Ar age
K/Ar age
11.4 ±2.6 (Gastil et al., 1999)
GULF OF CALIFORNIA
SW Isla Tiburón & Sauzal Basins
Feeder Dike
Cerro Starship Rhyodacite flow
Feeder Dike
Limit of Mapping
LA CRUZ FAULT
ARROYO SAUZAL
Tuffs of Hipat Mesa
Cerro Colorado Dacite flows
Qbv
Tec
Qoa
Td
Tcm
Tvc
Tb
Tda
Kt
Tcnm
Tbxv
Tvcg
Qal
29
24
22
37
19
34
3
33
4
32
25
15
5
13
50
N
0 1 2 3 4 KM
350000
355000
360000
3200000
3195000
3190000


SW
NE
La Cruz fault
volcanic
bx/congl.
basalt, volc.SS, lac. LS, dacitic-andesite
15-21 (G'99)
dacite, hb-andesite, volc. bx, volc. congl.
12-18 (G'99)
tonalite ~85 (GK, 1977)
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U/Pb age
Ar/Ar age
K/Ar age
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GULF OF CALIFORNIA
SW Isla Tiburón & Sauzal Basins
Feeder Dike
Cerro Ship Rhyodacite flow
Feeder Dike
Limit of Mapping
Tuffs of Hipat Mesa
Cerro Colorado Dacite flows
CRUZ
ARROYO
FAULT
SAUZAL
Qbv
Tec
Qoa
Tcm
Tvc
Tb
Tda
Kt
Td
Tcnm
Tbxv
Tvcg
Qal
24
29
37
22
34
19
3
4
33
32
15
25
5
13
50
N
0 1 2 3 4 KM
350000
355000
360000
3200000
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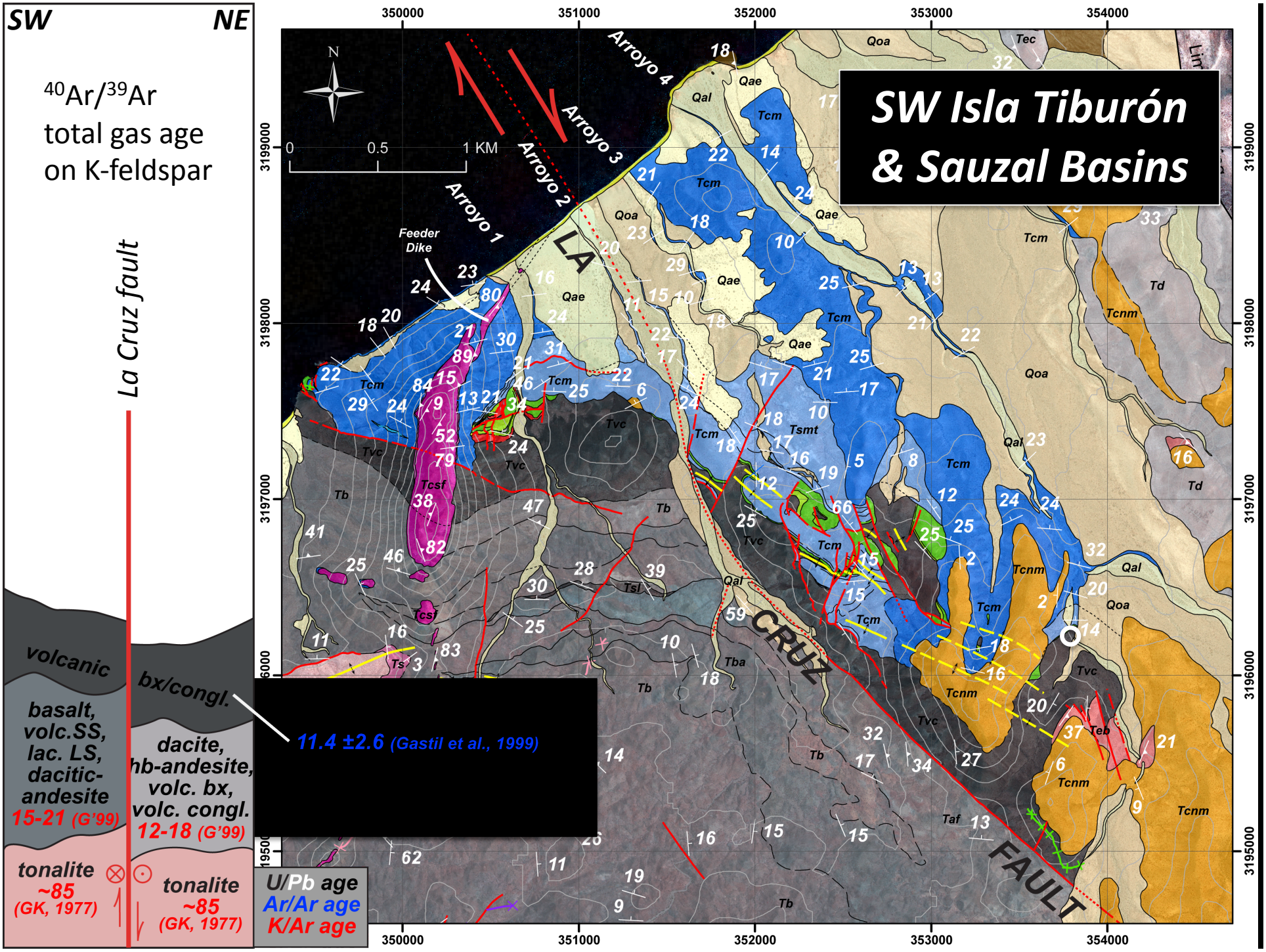
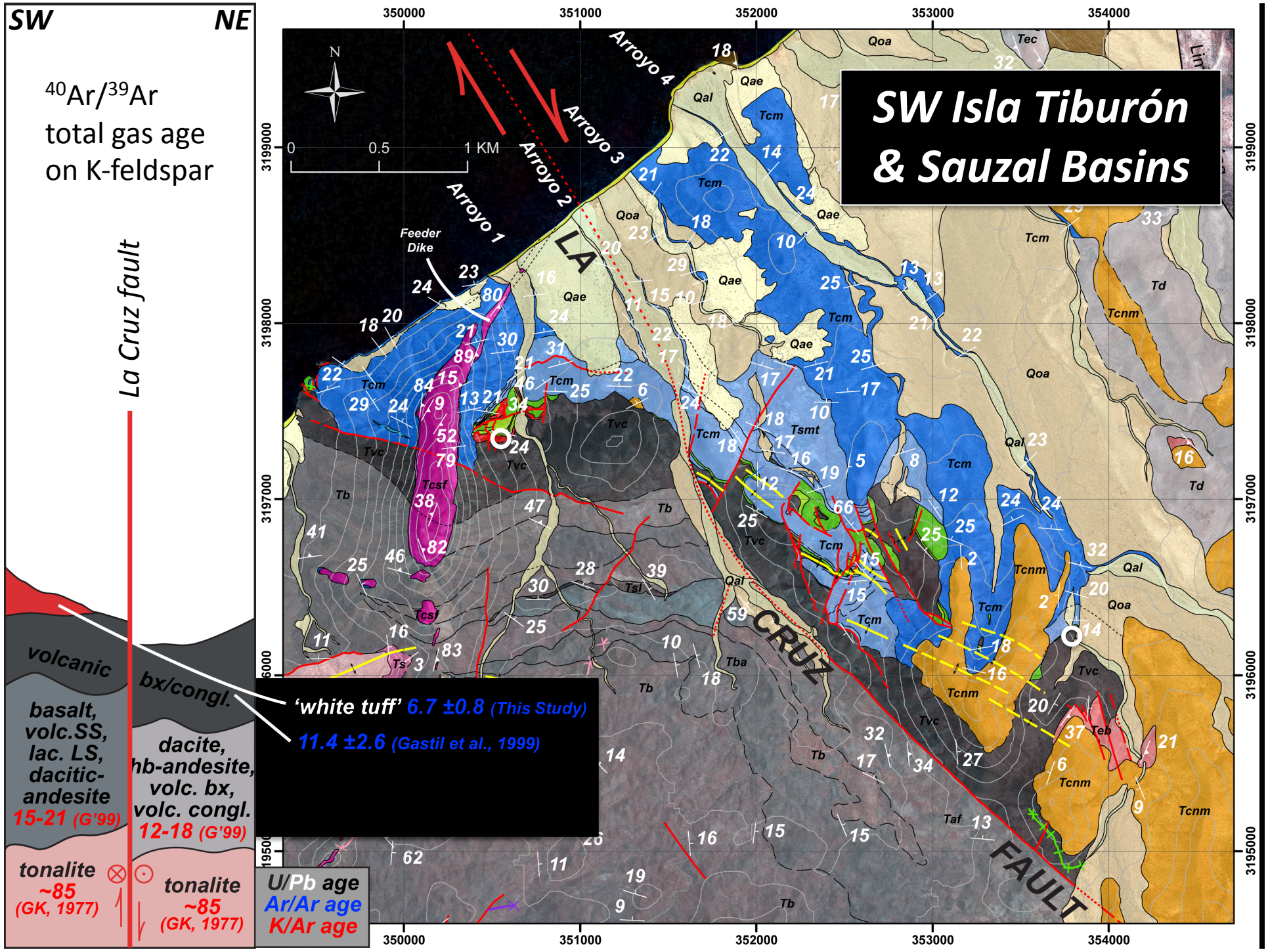
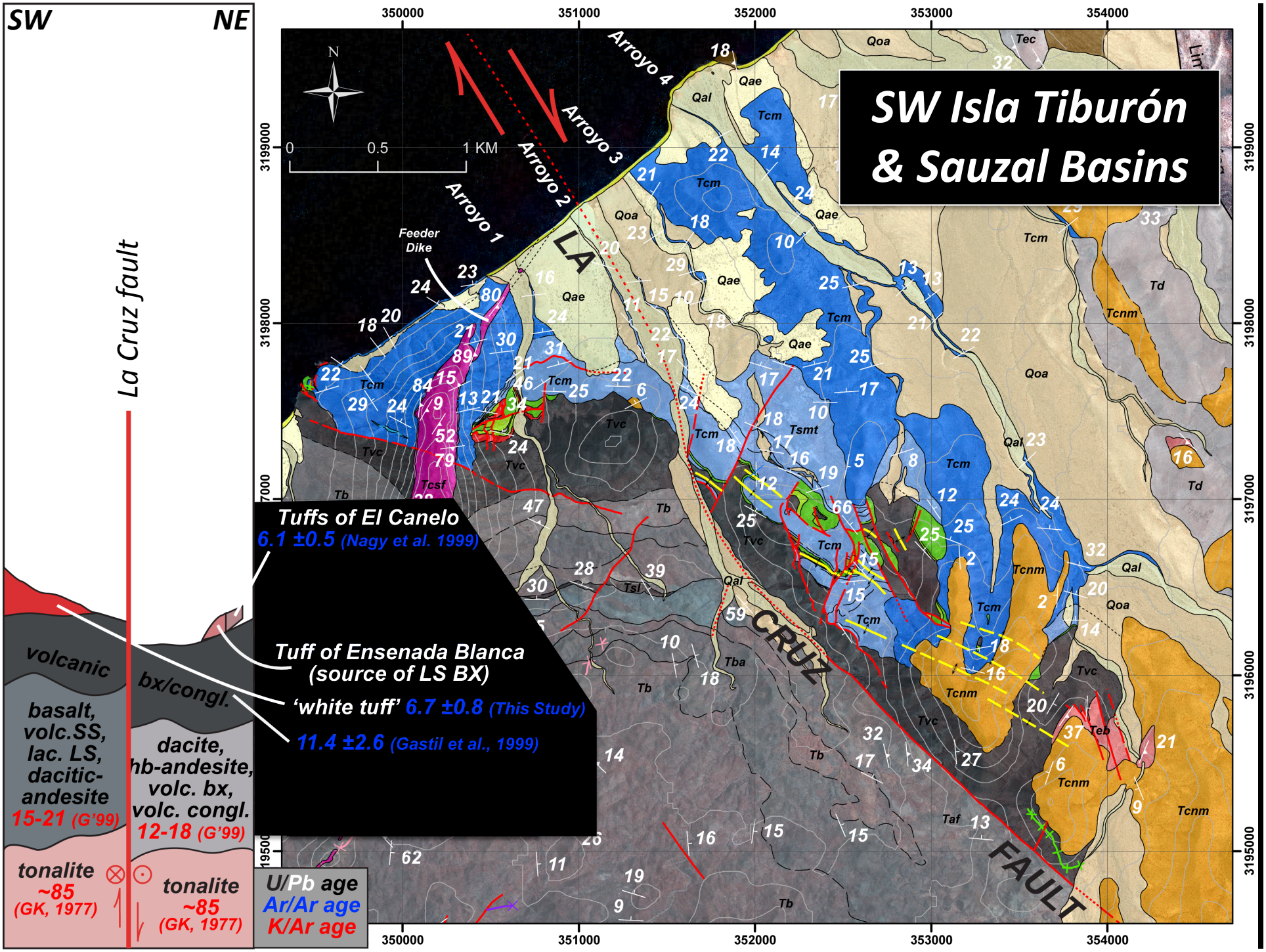
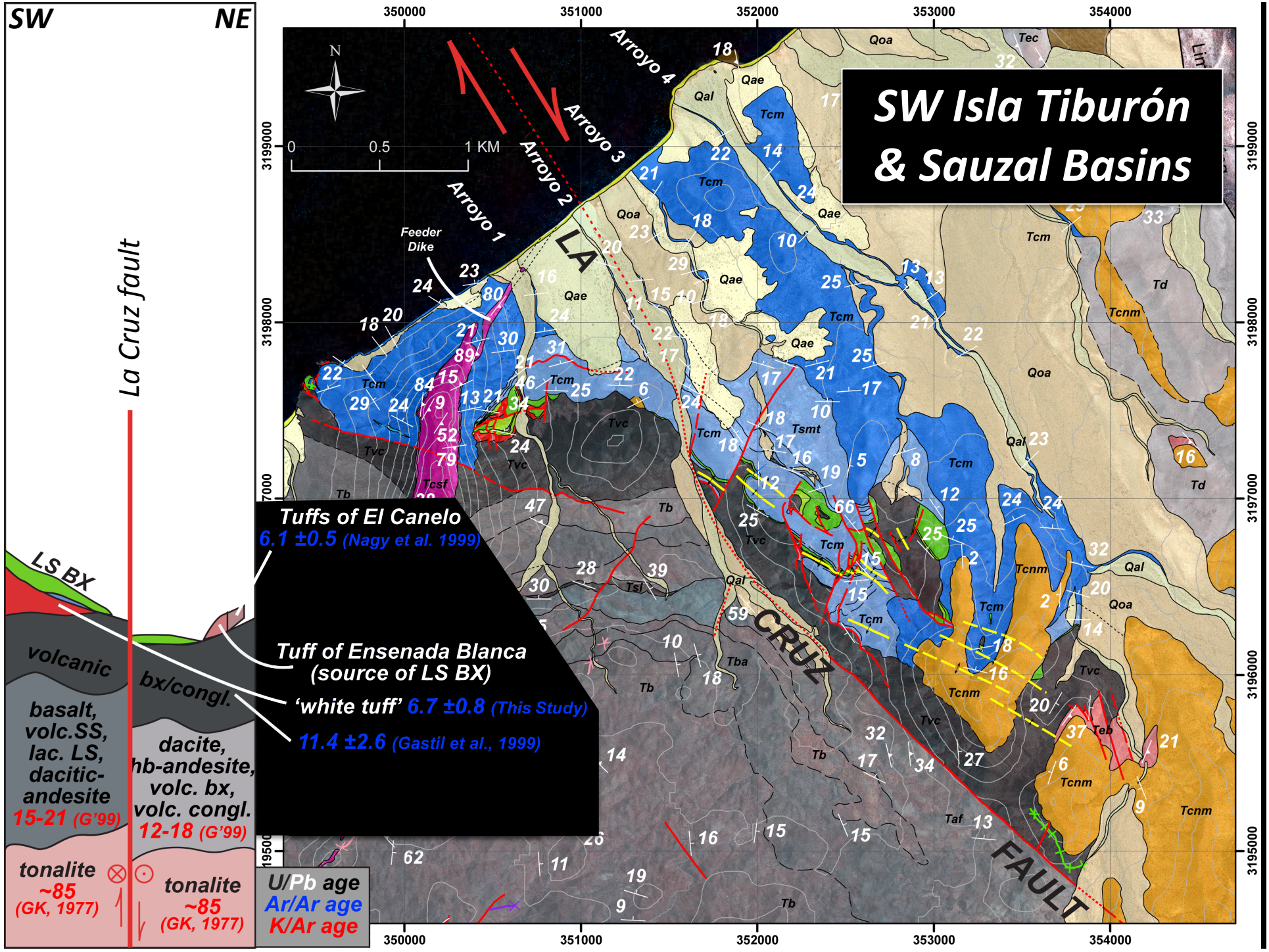
3190000


SW
NE
$^{40}Ar/^{39}Ar$ total gas age on K-feldspar
La Cruz fault
volcanic
bx/congl.
basalt, volc.SS, lac. LS, dacitic-andesite
15-21 (G'99)
dacite, hb-andesite, volc. bx, volc. congl.
12-18 (G'99)
tonalite ~85 (GK, 1977)
tonalite ~85 (GK, 1977)
11.4 ±2.6 (Gastil et al., 1999)
U/Pb age
Ar/Ar age
K/Ar age
SW Isla Tiburón & Sauzal Basins
Arroyo 1
Arroyo 2
Arroyo 3
Arroyo 4
Feeder Dike
LA CRUZ FAULT
N
0
0.5
1 KM
350000
351000
352000
353000
354000
3199000
3198000
3197000
3196000
3195000
Qae
Qal
Qoa
Tec
Tcm
Tcnm
Td
Tvc
Tb
Tsmt
Tsl
Tcsf
Tba
Teb
Taf


SW
NE
$^{40}Ar/^{39}Ar$ total gas age on K-feldspar
La Cruz fault
volcanic
bx/congl.
basalt, volc.SS, lac. LS, dacitic-andesite 15-21 (G'99)
dacite, hb-andesite, volc. bx, volc. congl. 12-18 (G'99)
tonalite ~85 (GK, 1977)
tonalite ~85 (GK, 1977)
'white tuff' 6.7 ±0.8 (This Study)
11.4 ±2.6 (Gastil et al., 1999)
U/Pb age
Ar/Ar age
K/Ar age
SW Isla Tiburón & Sauzal Basins
Arroyo 1
Arroyo 2
Arroyo 3
Arroyo 4
Feeder Dike
LA CRUZ FAULT
0 0.5 1 KM
N
350000
351000
352000
353000
354000
3199000
3198000
3197000
3196000
3195000


SW
NE
La Cruz fault
volcanic
bx/congl.
basalt, volc.SS, lac. LS, dacitic-andesite
15-21 (G'99)
dacite, hb-andesite, volc. bx, volc. congl.
12-18 (G'99)
tonalite ~85 (GK, 1977)
tonalite ~85 (GK, 1977)
Tuffs of El Canelo
6.1 ±0.5 (Nagy et al. 1999)
Tuff of Ensenada Blanca (source of LS BX)
'white tuff' 6.7 ±0.8 (This Study)
11.4 ±2.6 (Gastil et al., 1999)
U/Pb age
Ar/Ar age
K/Ar age
SW Isla Tiburón & Sauzal Basins
N
0
0.5
1 KM
Arroyo 4
Arroyo 3
Arroyo 2
Arroyo 1
Feeder Dike
LA CRUZ FAULT
350000
351000
352000
353000
354000
3199000
3198000
3197000
3196000
3195000


SW
NE
La Cruz fault
LS BX
volcanic
bx/congl.
basalt, volc.SS, lac. LS, dacitic-andesite
15-21 (G'99)
dacite, hb-andesite, volc. bx, volc. congl.
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U/Pb age
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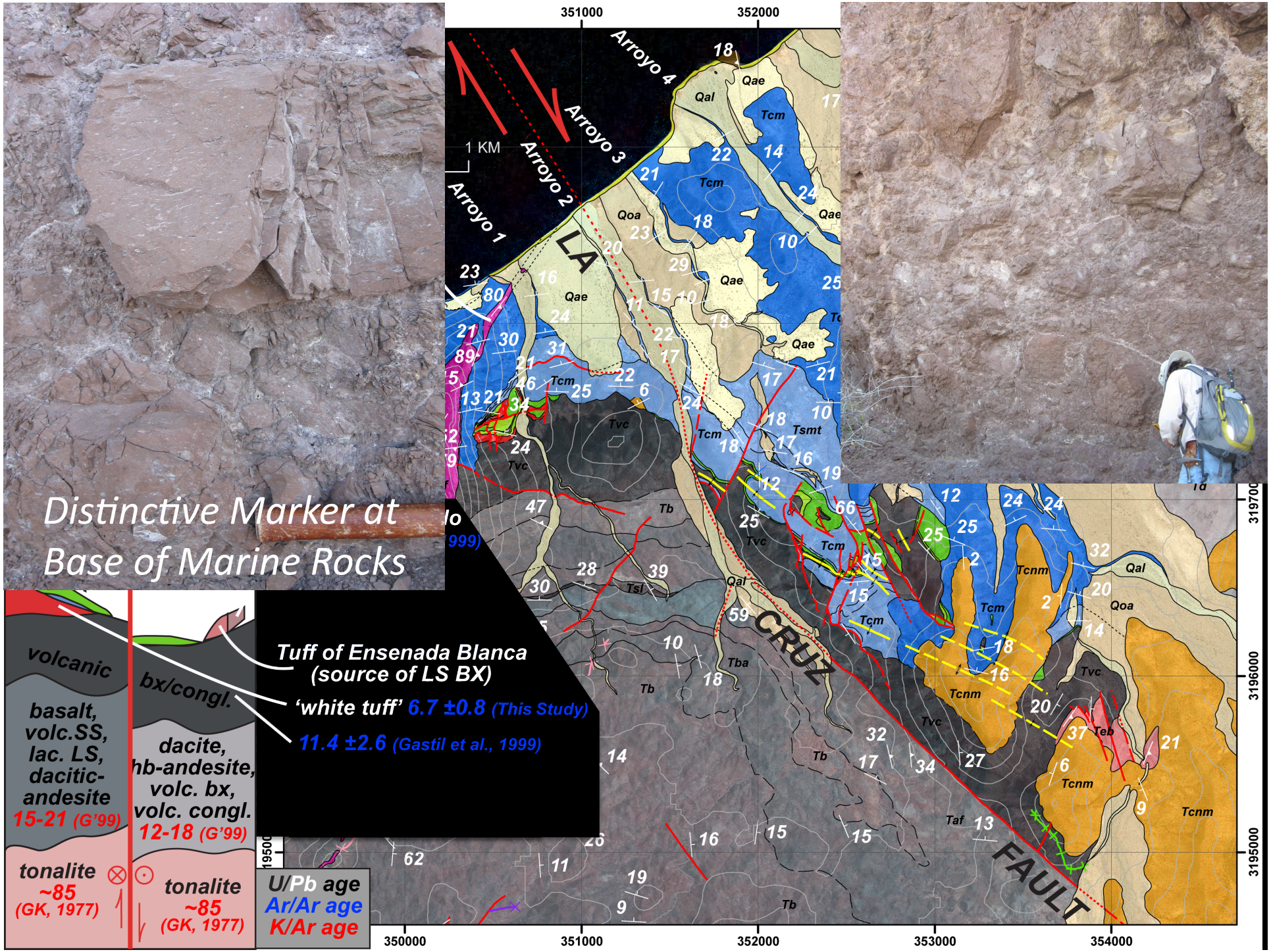
K/Ar age
SW Isla Tiburón & Sauzal Basins
Arroyo 1
Arroyo 2
Arroyo 3
Arroyo 4
Feeder Dike
LA CRUZ FAULT
N
0
0.5
1 KM
350000
351000
352000
353000
354000
3199000
3198000
3197000
3196000
3195000


Distinctive Marker at Base of Marine Rocks
volcanic
bx/congl.
basalt, volc.SS, lac. LS, dacitic-andesite
15-21 (G'99)
dacite, hb-andesite, volc. bx, volc. congl.
12-18 (G'99)
tonalite ~85 (GK, 1977)
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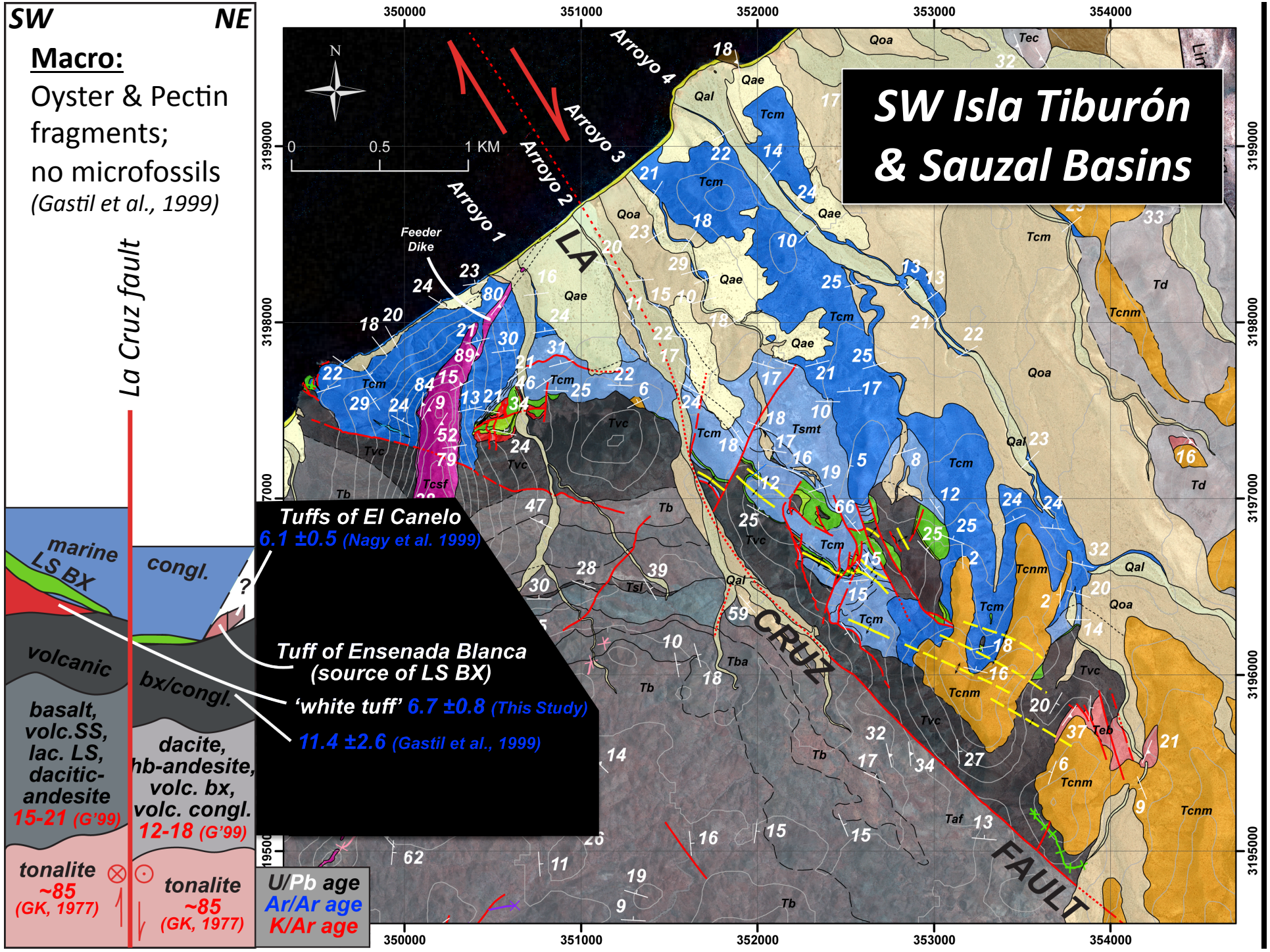
U/Pb age
Ar/Ar age
K/Ar age
Arroyo 4
Arroyo 3
Arroyo 2
Arroyo 1
1 KM
LA
CRUZ
FAULT
Qae
Qal
Qoa
Tcm
Tvc
Tb
Tba
Tsmt
Tsl
Tcnm
Teb
Taf
351000
352000
350000
353000
354000
3197000
3196000
3195000


SW
NE
Macro:
Oyster & Pectin fragments;
no microfossils
(Gastil et al., 1999)
La Cruz fault
marine LS BX
congl.
?
volcanic
bx/congl.
basalt, volc.SS, lac. LS, dacitic-andesite
15-21 (G'99)
dacite, hb-andesite, volc. bx, volc. congl.
12-18 (G'99)
tonalite ~85 (GK, 1977)
tonalite ~85 (GK, 1977)
SW Isla Tiburón & Sauzal Basins
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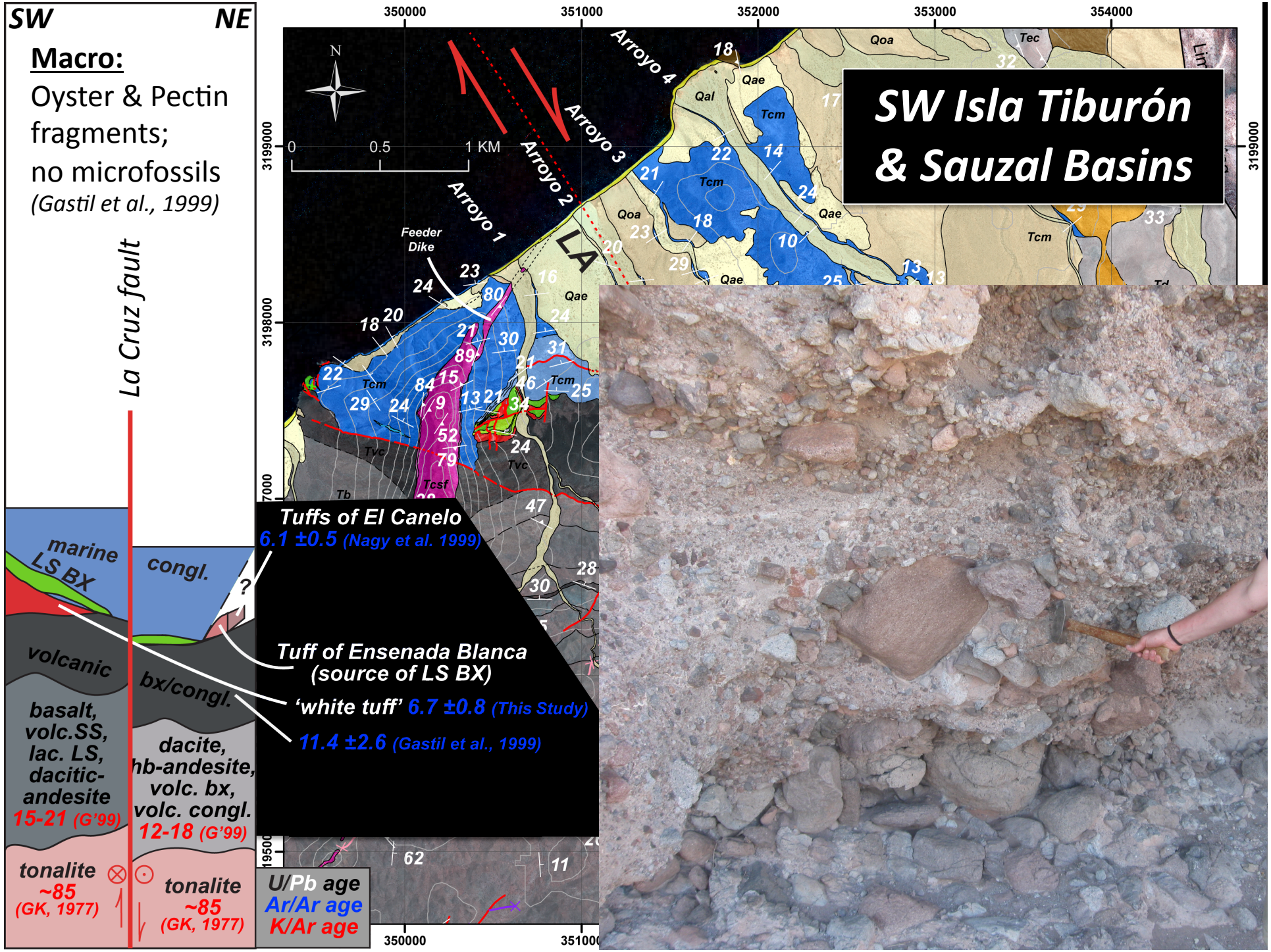
Tuff of Ensenada Blanca
(source of LS BX)
'white tuff' 6.7 ±0.8 (This Study)
11.4 ±2.6 (Gastil et al., 1999)
U/Pb age
Ar/Ar age
K/Ar age
Arroyo 1
Arroyo 2
Arroyo 3
Arroyo 4
Feeder Dike
LA CRUZ FAULT
0
0.5
1 KM
N
350000
351000
352000
353000
354000
3199000
3198000
3197000
3196000
3195000


SW
NE
Macro:
Oyster & Pectin fragments;
no microfossils
(Gastil et al., 1999)
La Cruz fault
marine LS BX
congl.
?
volcanic
bx/congl.
basalt, volc.SS, lac. LS, dacitic-andesite
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dacite, hb-andesite, volc. bx, volc. congl.
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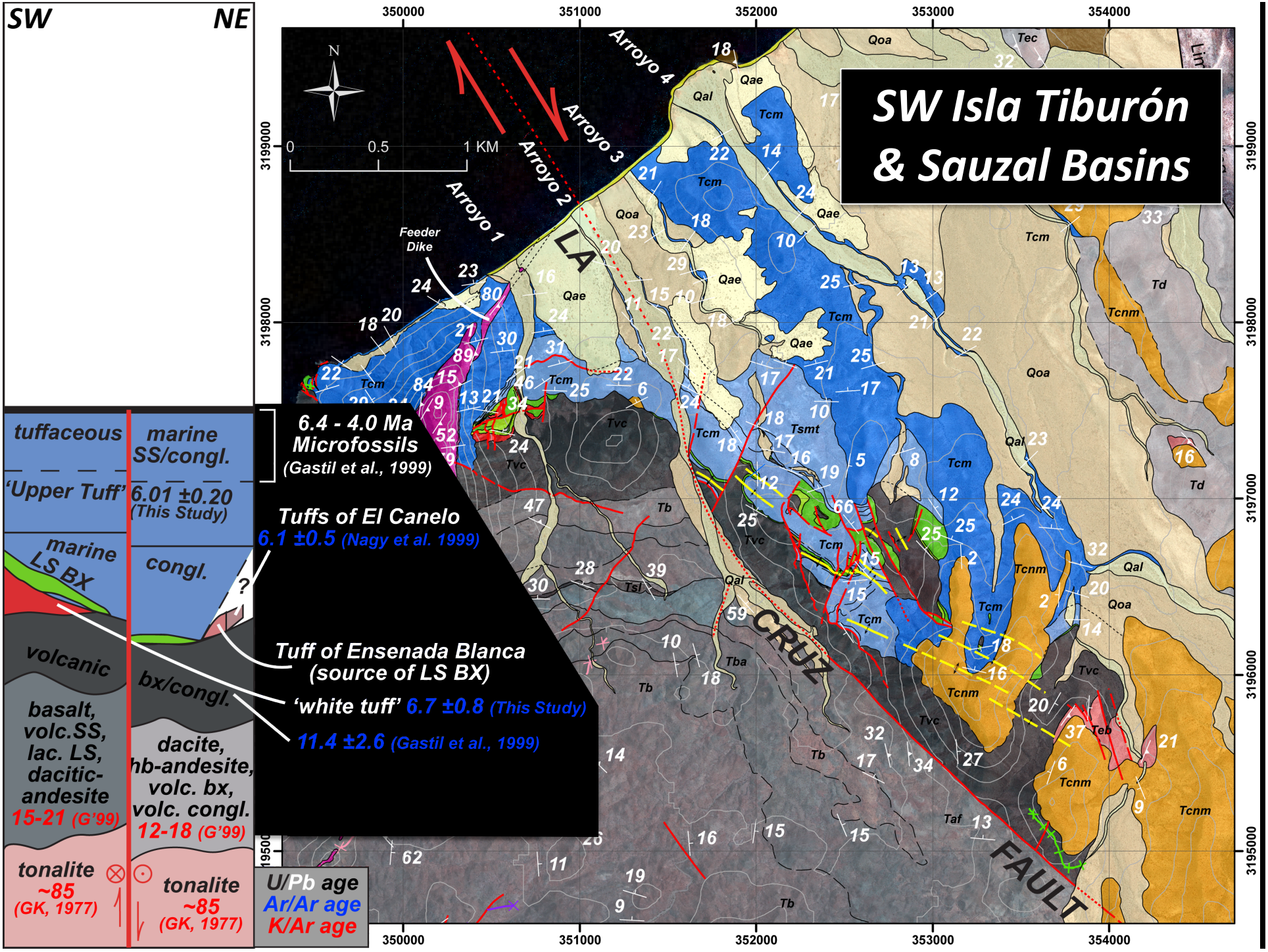
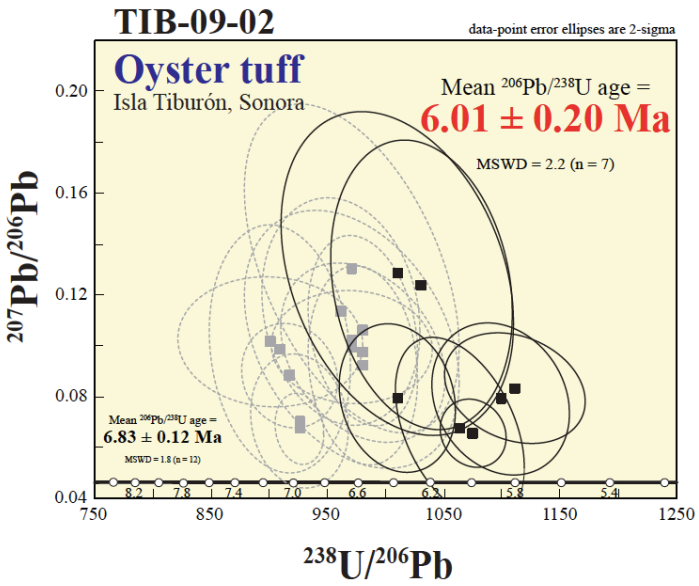
SW Isla Tiburón & Sauzal Basins
Arroyo 1
Arroyo 2
Arroyo 3
Arroyo 4
Feeder Dike
LA
Qae
Qal
Qoa
Tcm
Tvc
Tcsf
Tb
Tec
350000
351000
352000
353000
354000
3199000
3198000
0
0.5
1 KM
N


SW Isla Tiburón & Sauzal Basins
SW
NE
N
0
0.5
1 KM
Arroyo 1
Arroyo 2
Arroyo 3
Arroyo 4
Feeder Dike
LA
CRUZ
FAULT
350000
351000
352000
353000
354000
3199000
3198000
3197000
3196000
3195000
tuffaceous
marine SS/congl.
'Upper Tuff'
6.01 ±0.20 (This Study)
marine LS BX
congl.
volcanic
bx/congl.
basalt, volc.SS, lac. LS, dacitic-andesite 15-21 (G'99)
dacite, hb-andesite, volc. bx, volc. congl. 12-18 (G'99)
tonalite ~85 (GK, 1977)
tonalite ~85 (GK, 1977)
6.4 - 4.0 Ma Microfossils (Gastil et al., 1999)
Tuffs of El Canelo 6.1 ±0.5 (Nagy et al. 1999)
Tuff of Ensenada Blanca (source of LS BX)
'white tuff' 6.7 ±0.8 (This Study)
11.4 ±2.6 (Gastil et al., 1999)
U/Pb age
Ar/Ar age
K/Ar age


TIB-09-02
data-point error ellipses are 2-sigma
Oyster tuff
Isla Tiburón, Sonora
Mean 206Pb/238U age =
6.01 ± 0.20 Ma
MSWD = 2.2 (n = 7)
Mean 206Pb/238U age =
6.83 ± 0.12 Ma
MSWD = 1.8 (n = 12)
207Pb/206Pb
238U/206Pb
0.20
0.16
0.12
0.08
0.04
750
850
950
1050
1150
1250

tuffaceous
marine SS/congl.
'Upper Tuff' 6.01 ±0.20 (This Study)
marine LS BX
congl.
volcanic
bx/congl.
basalt, volc.SS, lac. LS, dacitic-andesite 15-21 (G'99)
dacite, hb-andesite, volc. bx, volc. congl. 12-18 (G'99)
tonalite ~85 (GK, 1977)
tonalite ~85 (GK, 1977)
Microfossils (Gastil et al., 1999)
Tuffs of El Canelo 6.1 ±0.5 (Nagy et al. 1999)
Tuff of Ensenada Blanca (source of LS BX)
'white tuff' 6.7 ±0.8 (This Study)
11.4 ±2.6 (Gastil et al., 1999)
U/Pb age
Ar/Ar age
K/Ar age
CRUZ FAULT
352000
350000
351000
352000
353000
354000
3197000
3196000
3195000

(Tsmt) Tuffaceous Marine SS & Congl

Macro:

oyster, pectin, barnacle, gastropod

Micro:

benthic & planktonic forams, calcareous nannoplankton, ostracods *(Gastil et al., 1999)*

Planktonic species

Globigerina sp. cf. *G. apertura* Cushman
Globigerina decoraperta Takayanagi & Saito
Globigerina falconensis Blow
Globigerina quinqueloba Natland
Globigerina woodi Jenkins
Globigerinella sp.
Globigerinoides bollii Blow
Globigerinoides bulloideus Crescenti
Globigerinoides conglobatus (Brady)
Globigerinoides extremus Bolli & Bermudez
Globigerinoides obliquus Bolli
Globigerinoides ruber, s.l. (d'Orbigny)
Globoquadrina venezuelana (Hedberg)
Globorotalia sp. cf. *G. anfracta* (Parker)
Globorotalia sp. aff. *G. limbata* (Fornasini)
Globorotalia menardii, s.l. (Parker, Jones, & Brady)
Pulleniatina primalis Banner & Blow

Benthic species

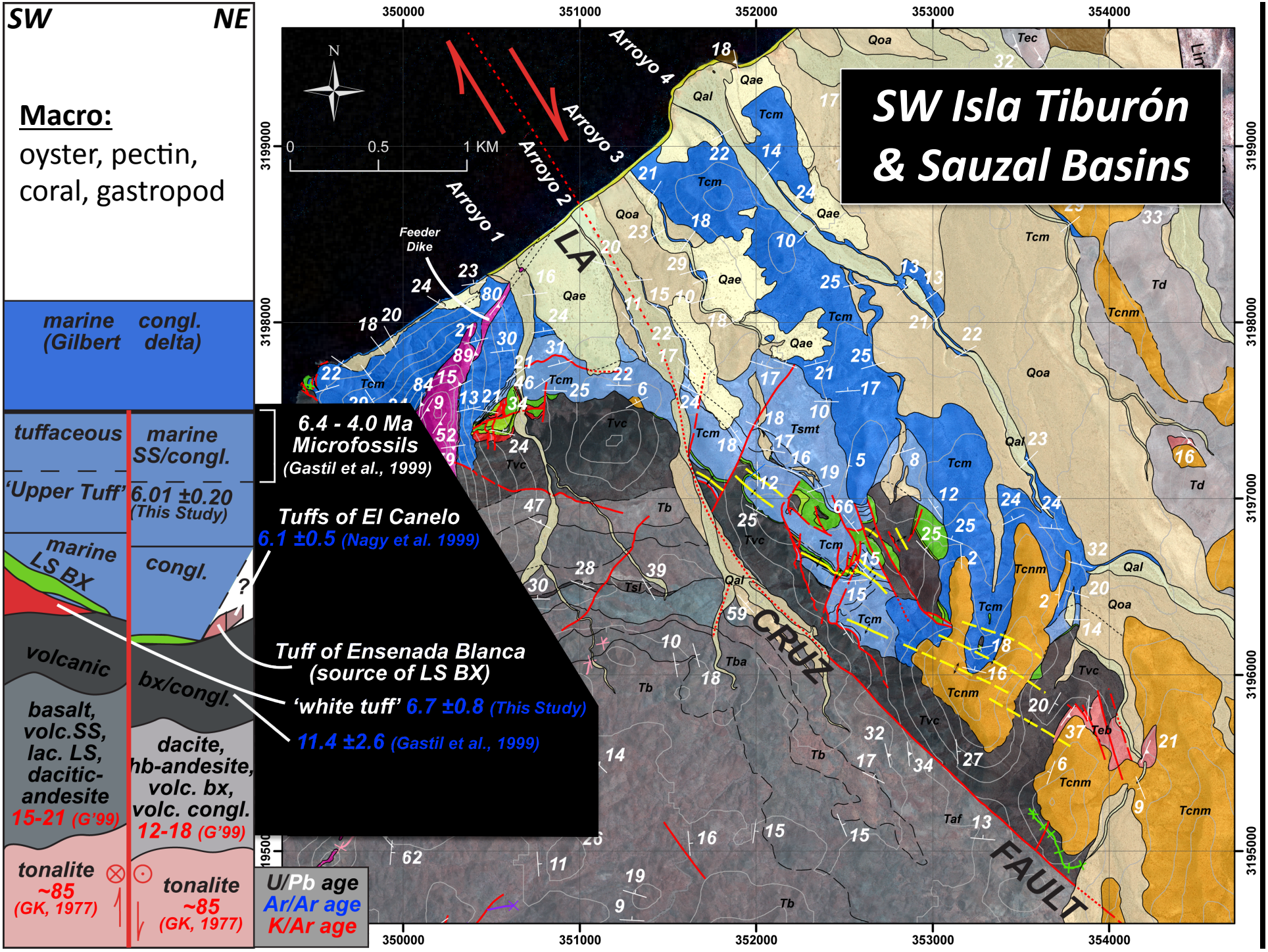
Amphistegina gibbosa d'Orbigny
Bolivina alata effusa Cushman & Todd
Bolivina pisciformis Heron-Allen & Earland
Bolivina spp.
Buccella sp.
Bulimina auriculata Bailey
Cancris auricula (Fitchel & Moll)
Cassidulina cushmani R.C. and K.C. Stewart
Cassidulina delicata Cushman
Cibicides mckannai Galloway & Wissler
Cibicides sp. cf. *C. reflugens* Montfort
Cibicides sp.
Elphidium crispum (Linné)
Elphidium sp.
Eponides antillarum (d'Orbigny)
Florilus basispinata (Cushman & Moyer)
Florilus miocenica stella (Cushman & Moyer)
Florilus sp.
Gaudryina sp.
Guttulina sp.
Hanzawaia americanus (Cushman)
Hanzawaia (Cancris) *bertheloti* (d'Orbigny)
Hanzawaia concentrica (Cushman)
Hanzawaia nitidula (Bandy)
Hanzawaia (*Cancris*) *panamensis* (Natland)
Hanzawaia (*Cancris*) *panamensis* (Natland) var. A
Lenticulina sp. aff. *L. americanus* (Cushman)
Lenticulina sp. aff. *L. calcar* (Linné)
Lenticulina limbata (Linné)
Lenticulina spp.
Loxostomum bradyi (Asano)
Marginulina papillata Coryell and Rivero
Planulina ariminensis (d'Orbigny)
Planulina ornata (d'Orbigny)
Pullenia salisburyi R.E. and K.C. Stewart
Rotorbinella turbinata (Cushman)
Siphotextularia sp. aff. *S. affinis* (Fornasini)
Textularia sp.
Trifarina spp.
Uvigerina excellens Todd
Uvigerina proboscidea Schwager
Valvulineria inflata (d'Orbigny)

foraminiferal zones N17B to N19

6.4–4.0 Ma age range

Table 10. Calcareous Nannoplankton

Taxon
Braarudosphaera bigelowi
Calcidiscus leptoporus
Coccolithus pelagicus
Dictyococcites antarcticus
Dictyococcites productus
Discoaster spp.
Helicosphaera carteri
Reticulofenestra haqii
Sphenolithus abies
Sphenolithus moriformis
Sphenolithus neoabies
Thoracosphaera sp.

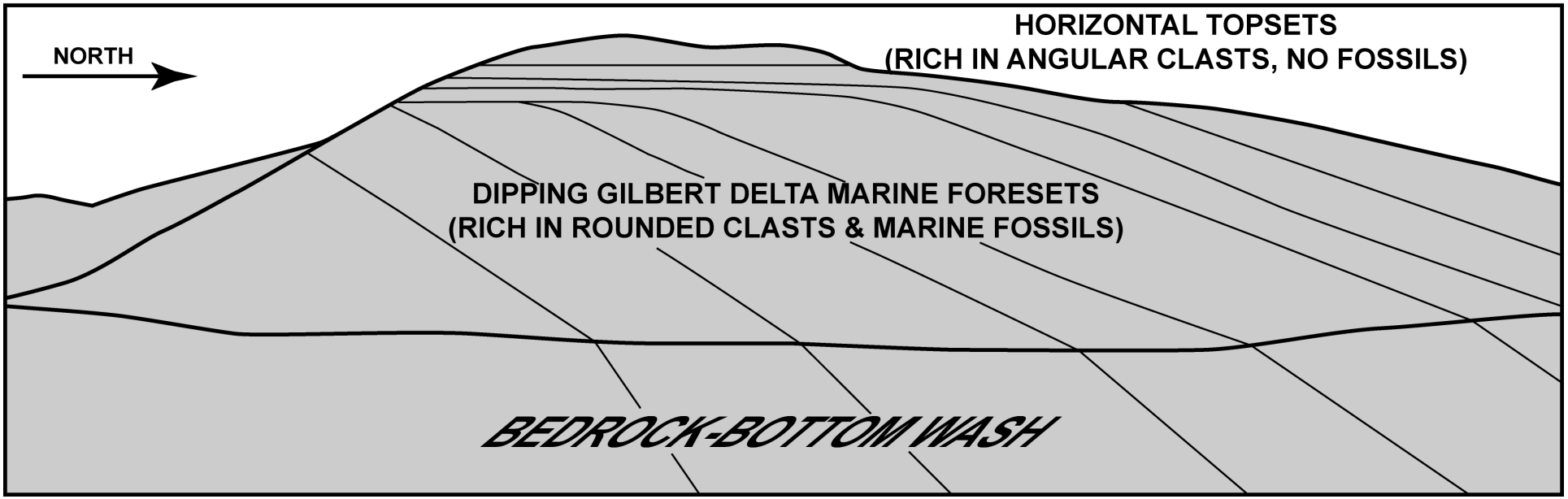

SW
NE
Macro:
oyster, pectin, coral, gastropod
marine (Gilbert delta)
congl.
tuffaceous
marine SS/congl.
'Upper Tuff'
6.01 ±0.20 (This Study)
marine LS BX
congl.
?
volcanic
bx/congl.
basalt, volc.SS, lac. LS, dacitic-andesite
15-21 (G'99)
dacite, hb-andesite, volc. bx, volc. congl.
12-18 (G'99)
tonalite ~85 (GK, 1977)
tonalite ~85 (GK, 1977)
6.4 - 4.0 Ma Microfossils (Gastil et al., 1999)
Tuffs of El Canelo
6.1 ±0.5 (Nagy et al. 1999)
Tuff of Ensenada Blanca (source of LS BX)
'white tuff' 6.7 ±0.8 (This Study)
11.4 ±2.6 (Gastil et al., 1999)
U/Pb age
Ar/Ar age
K/Ar age
SW Isla Tiburón & Sauzal Basins
N
0
0.5
1 KM
Arroyo 4
Arroyo 3
Arroyo 2
Arroyo 1
Feeder Dike
LA
CRUZ
FAULT
350000
351000
352000
353000
354000
3199000
3198000
3197000
3196000
3195000

Marine Foresets & Non-marine Topsets

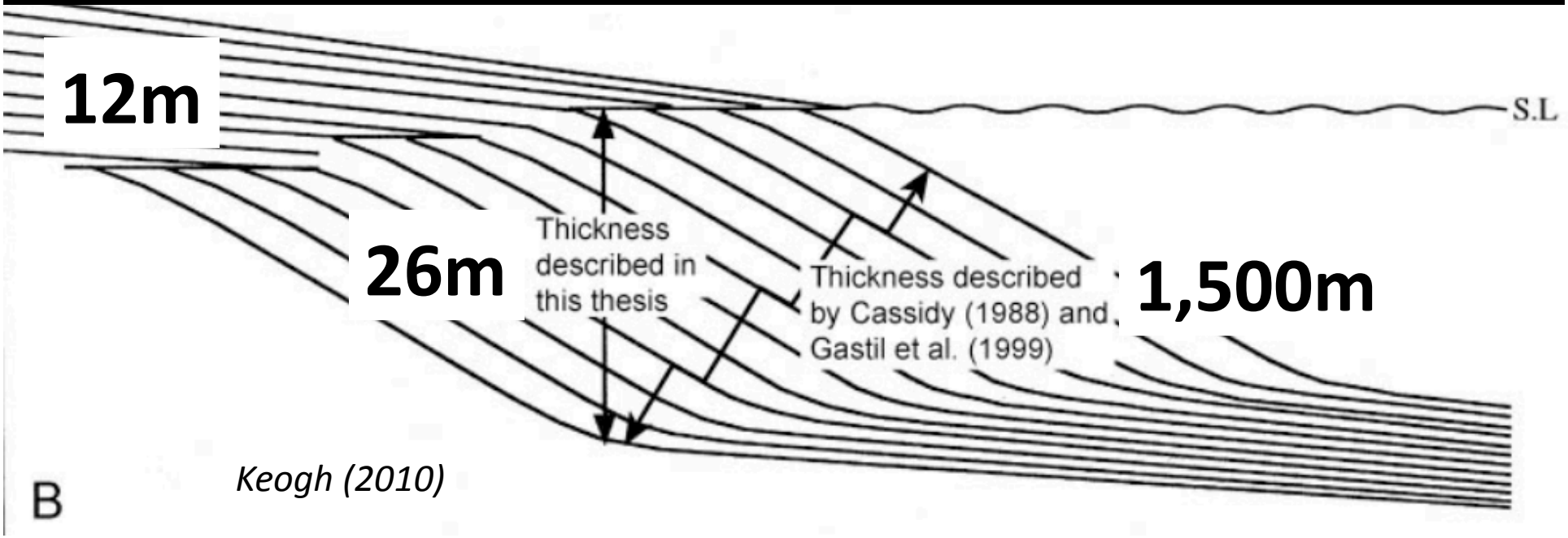
Marine Foresets & Non-marine Topsets

Vertical burrows in dipping beds
- bed inclination is depositional, not tectonic

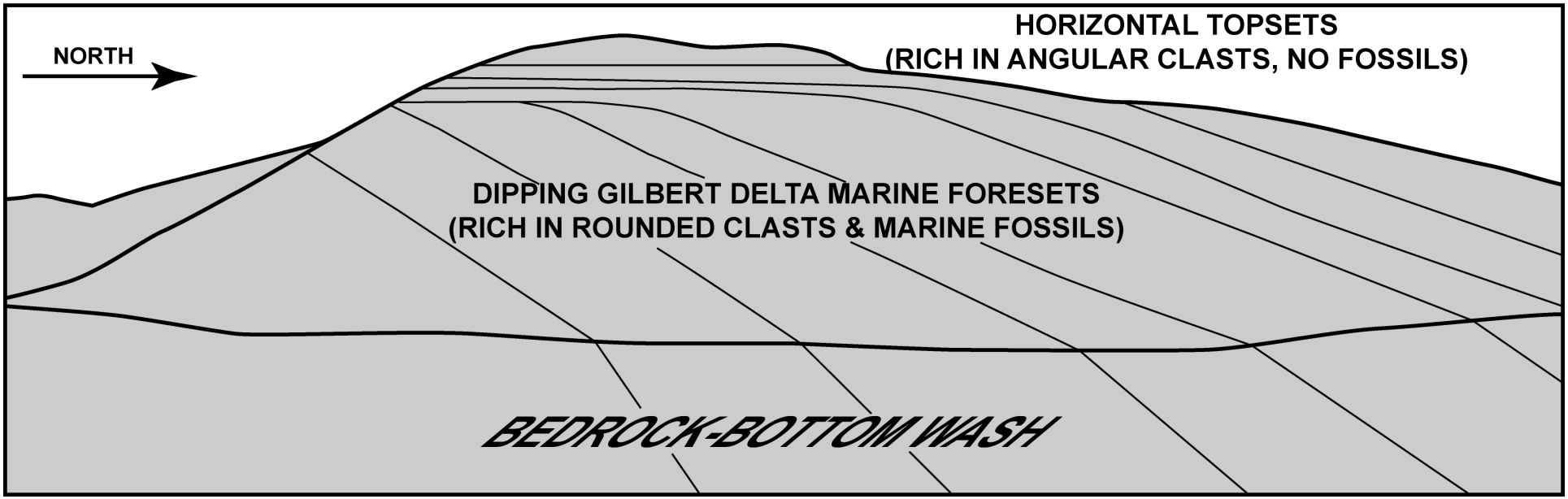
Marine Foresets & Non-marine Topsets

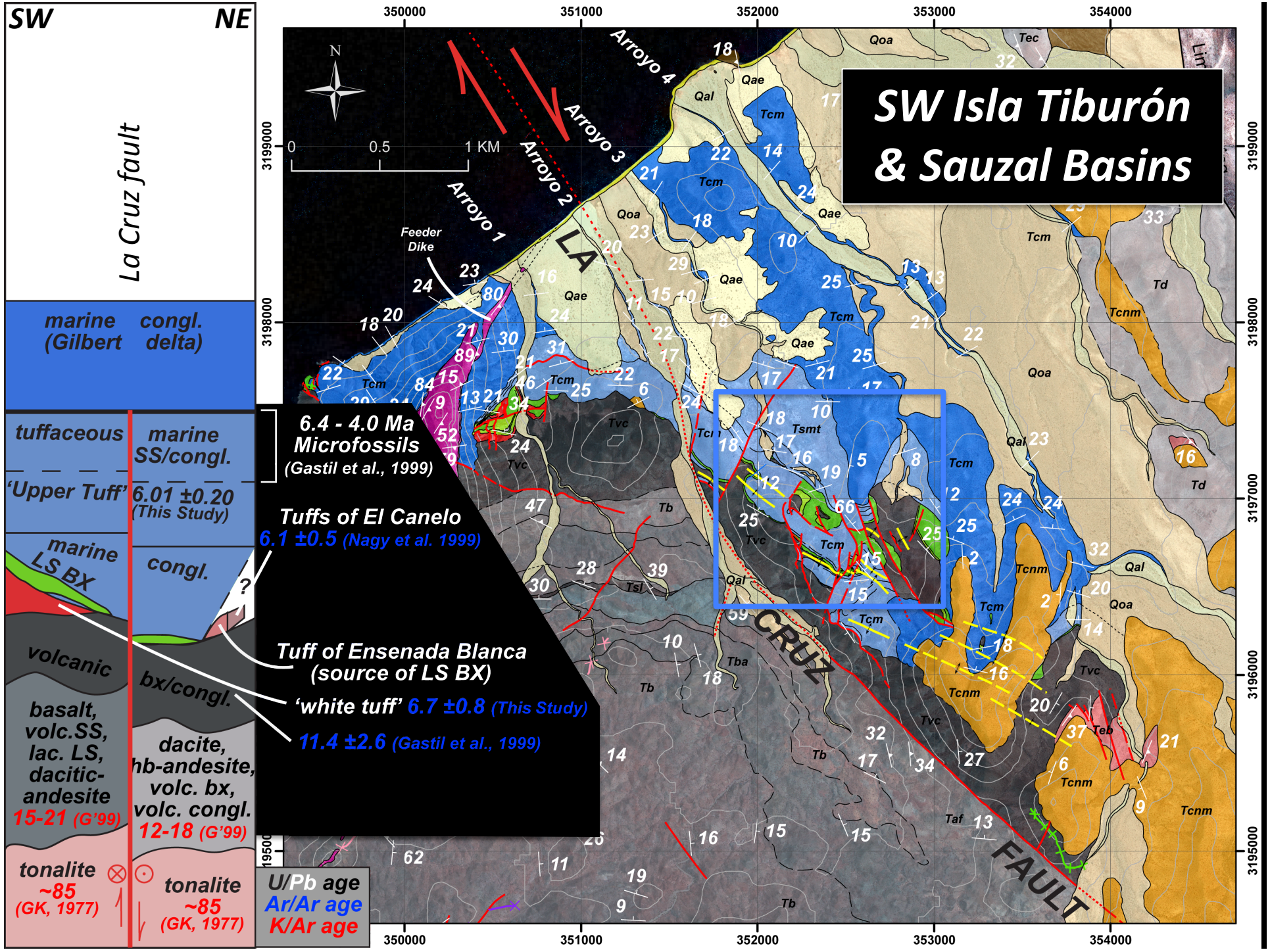


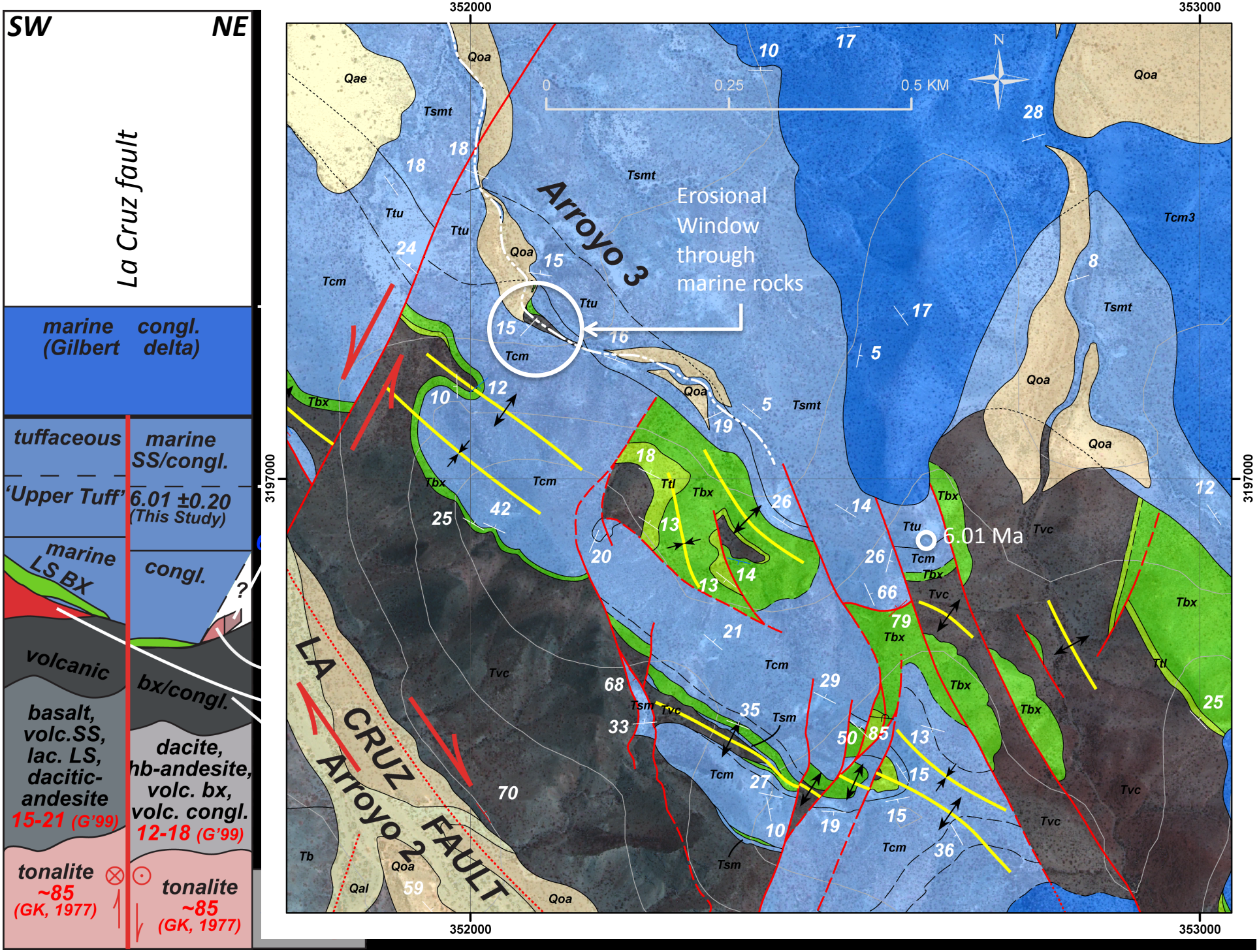
Marine Foresets & Non-marine Topsets

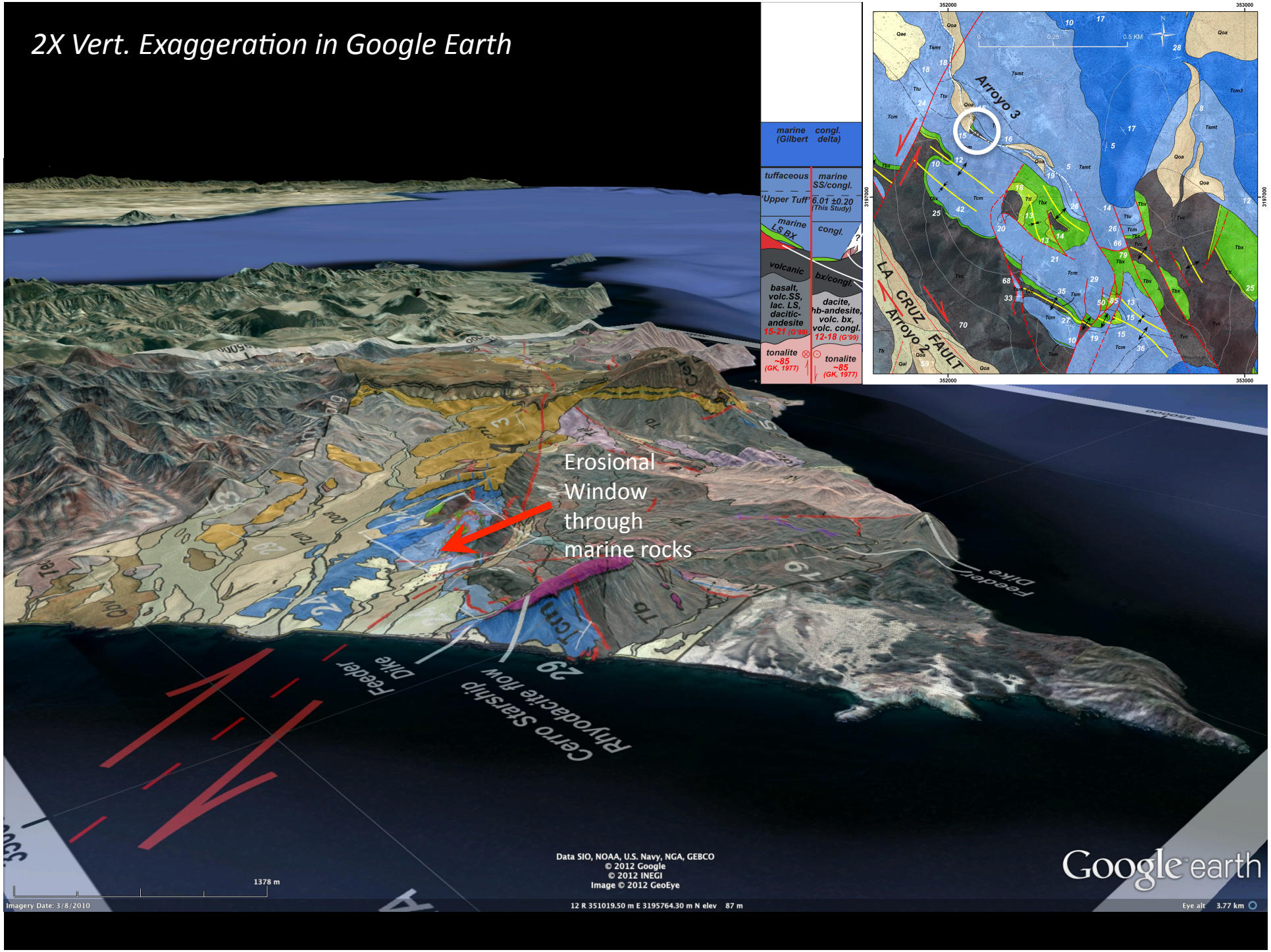


Keogh (2010)

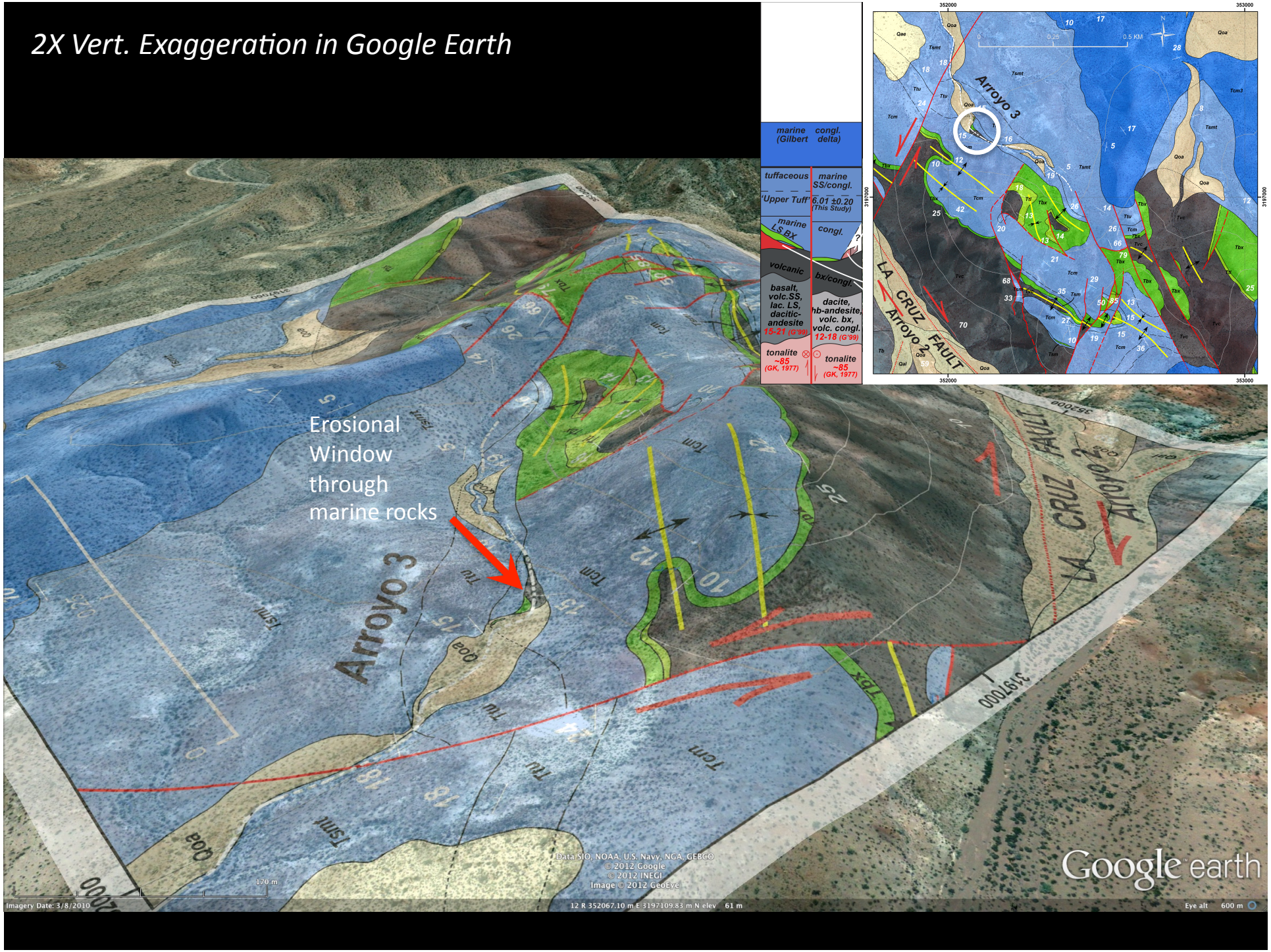



SW
NE
La Cruz fault
marine (Gilbert delta)
congl.
tuffaceous
marine SS/congl.
'Upper Tuff'
6.01 ±0.20 (This Study)
marine LS BX
congl.
?
volcanic
bx/congl.
basalt, volc.SS, lac. LS, dacitic-andesite
15-21 (G'99)
dacite, hb-andesite, volc. bx, volc. congl.
12-18 (G'99)
tonalite ~85 (GK, 1977)
tonalite ~85 (GK, 1977)
6.4 - 4.0 Ma Microfossils (Gastil et al., 1999)
Tuffs of El Canelo 6.1 ±0.5 (Nagy et al. 1999)
Tuff of Ensenada Blanca (source of LS BX)
'white tuff' 6.7 ±0.8 (This Study)
11.4 ±2.6 (Gastil et al., 1999)
U/Pb age
Ar/Ar age
K/Ar age
SW Isla Tiburón & Sauzal Basins
Arroyo 1
Arroyo 2
Arroyo 3
Arroyo 4
Feeder Dike
LA CRUZ FAULT
N
0
0.5
1 KM
350000
351000
352000
353000
354000
3199000
3198000
3197000
3196000
3195000

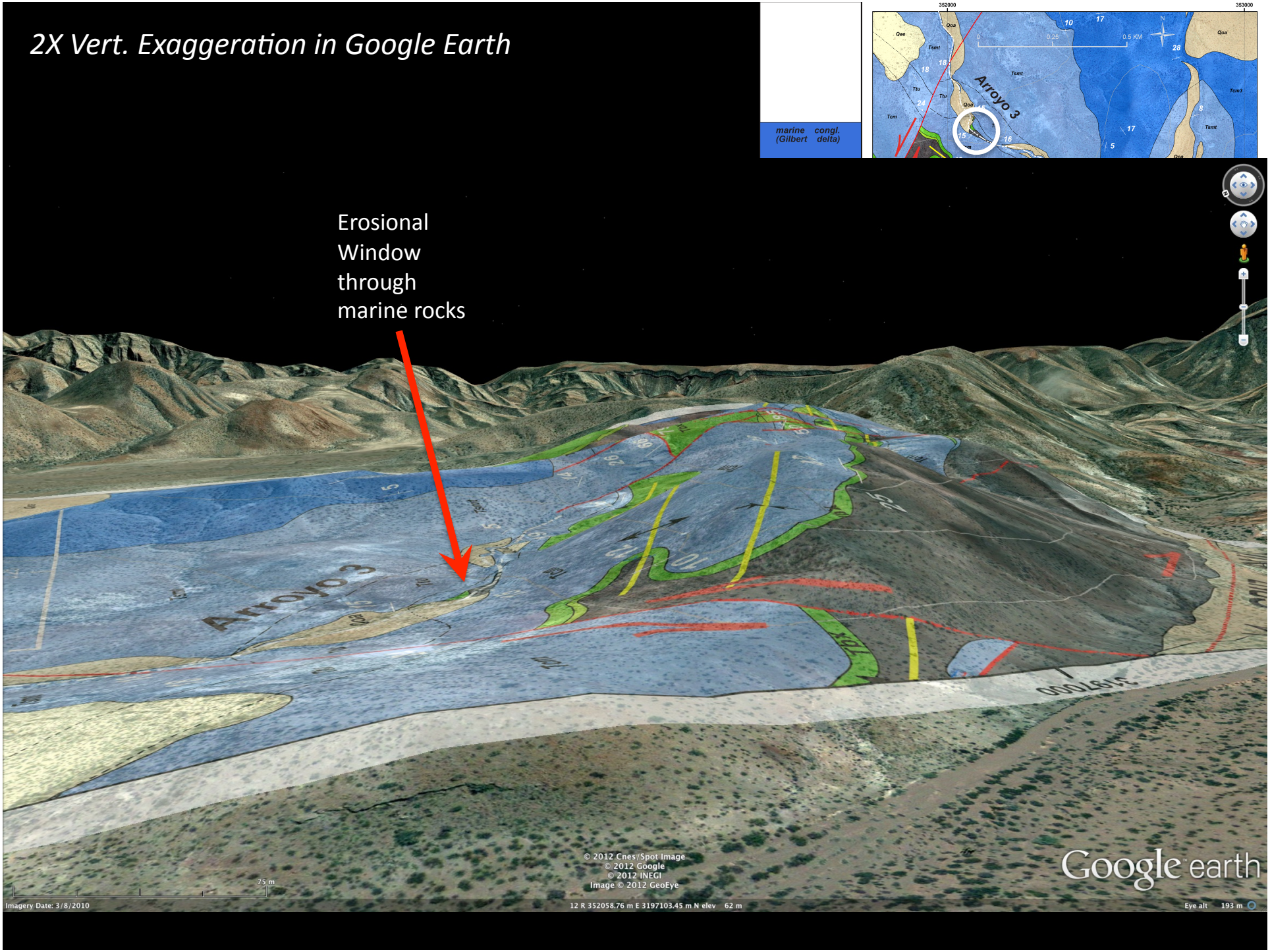

SW
NE
La Cruz fault
marine (Gilbert delta)
congl.
tuffaceous
marine SS/congl.
'Upper Tuff'
6.01 ±0.20
(This Study)
marine LS BX
congl.
?
volcanic
bx/congl.
basalt, volc.SS, lac. LS, dacitic-andesite
15-21 (G'99)
dacite, hb-andesite, volc. bx, volc. congl.
12-18 (G'99)
tonalite ~85 (GK, 1977)
tonalite ~85 (GK, 1977)
352000
353000
3197000
0
0.25
0.5 KM
N
Arroyo 3
Erosional Window through marine rocks
6.01 Ma
LA CRUZ FAULT
Arroyo 2
Qae
Qoa
Qal
Tsmt
Ttu
Tcm
Tcm3
Tbx
Ttl
Tvc
Tsm
Tb


2X Vert. Exaggeration in Google Earth
marine (Gilbert delta)
congl.
tuffaceous "Upper Tuff"
marine SS/congl.
6.01 ±0.20 (This Study)
marine LS,bx
congl.
volcanic
bx/congl.
basalt, volc.SS, lac. LS, dacitic-andesite
15-21 (G'99)
dacite, hb-andesite, volc. bx, volc. congl.
12-18 (G'99)
tonalite ~85 (GK, 1977)
tonalite ~85 (GK, 1977)
Arroyo 3
Arroyo 2
LA CRUZ FAULT
Erosional Window through marine rocks
Cerro Starship Rhyodacite flow
Feeder Dike
Feeder Dike
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2012 Google
© 2012 INEGI
Image © 2012 GeoEye
Google earth
Imagery Date: 3/8/2010
12 R 351019.50 m E 3195764.30 m N elev 87 m
Eye alt 3.77 km
1378 m

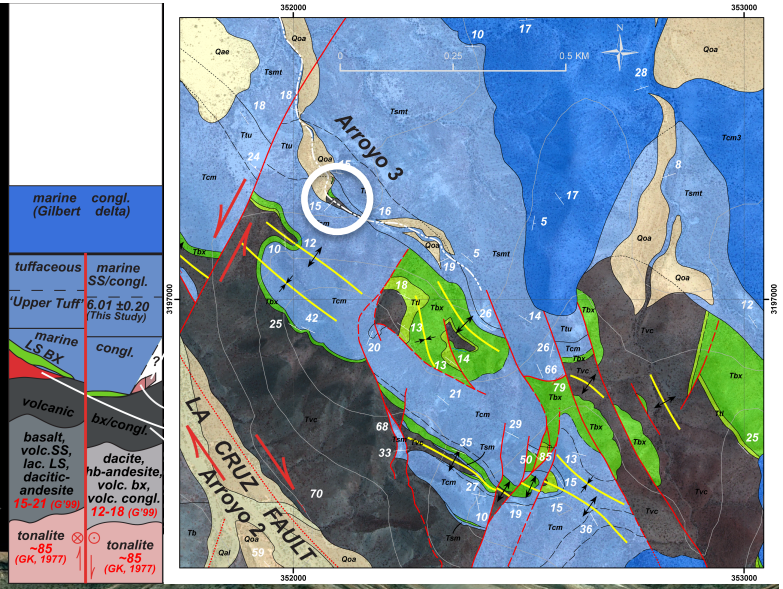
2X Vert. Exaggeration in Google Earth

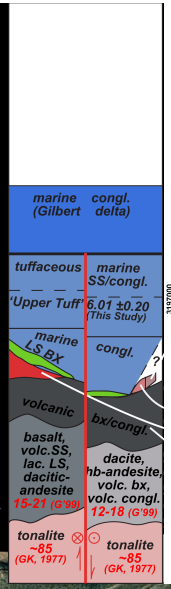


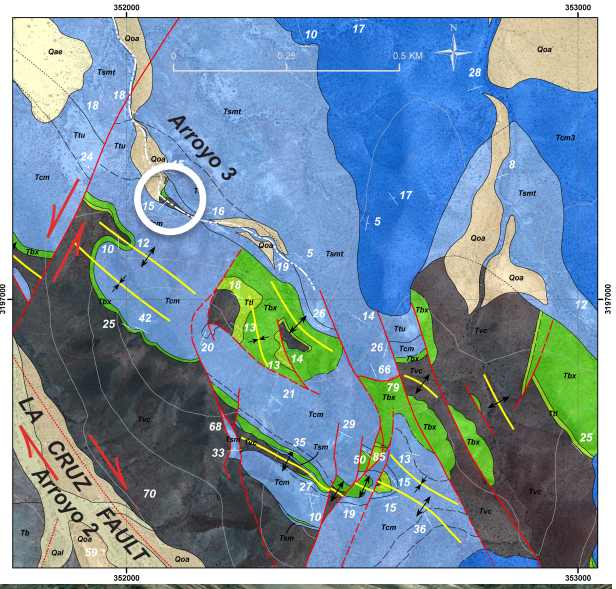
2X Vert. Exaggeration in Google Earth



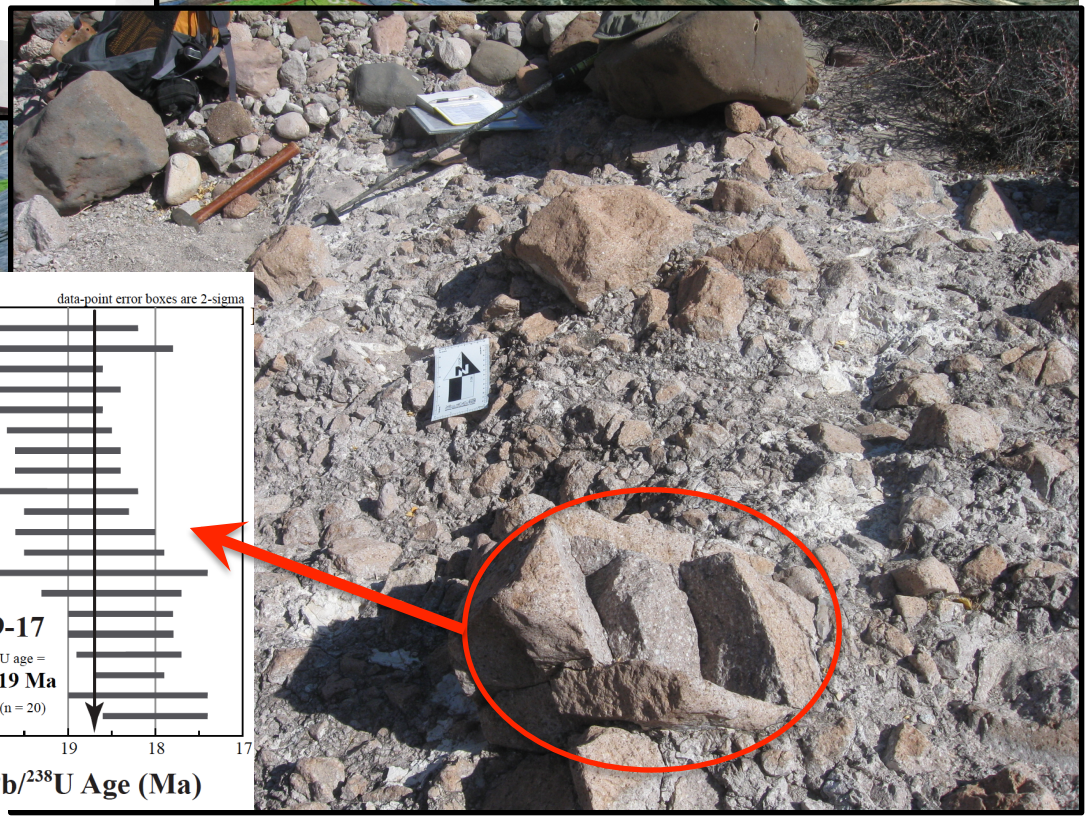
We located exact sample location of published 12.9 Ma marine rocks. Exposure is within Erosional Window.

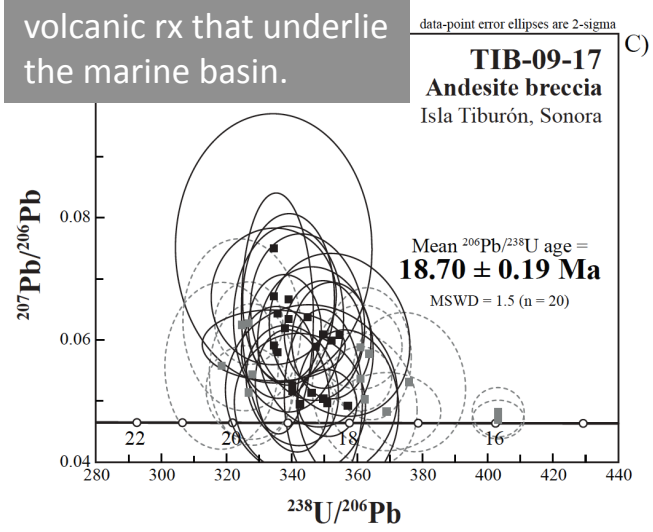


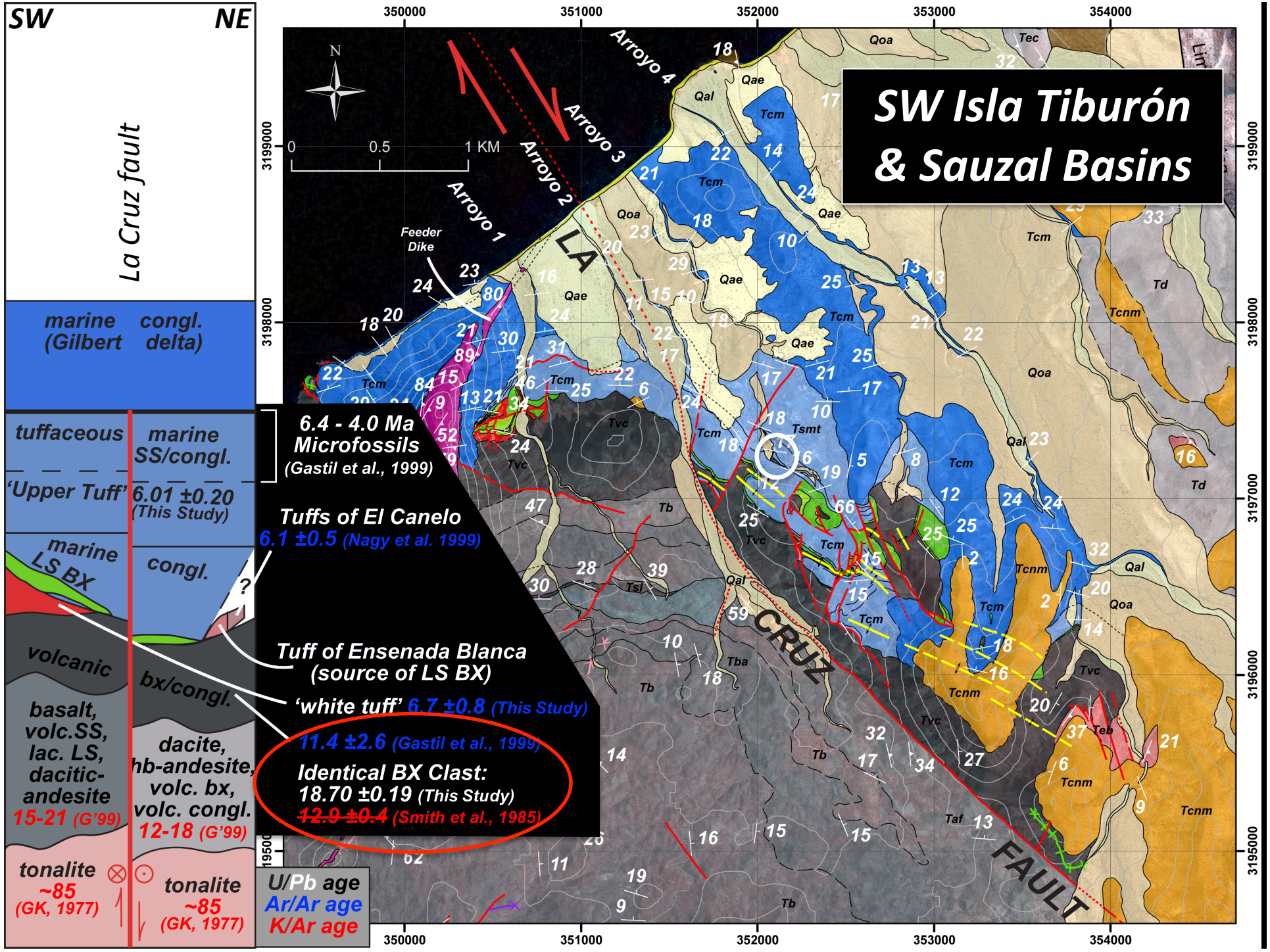


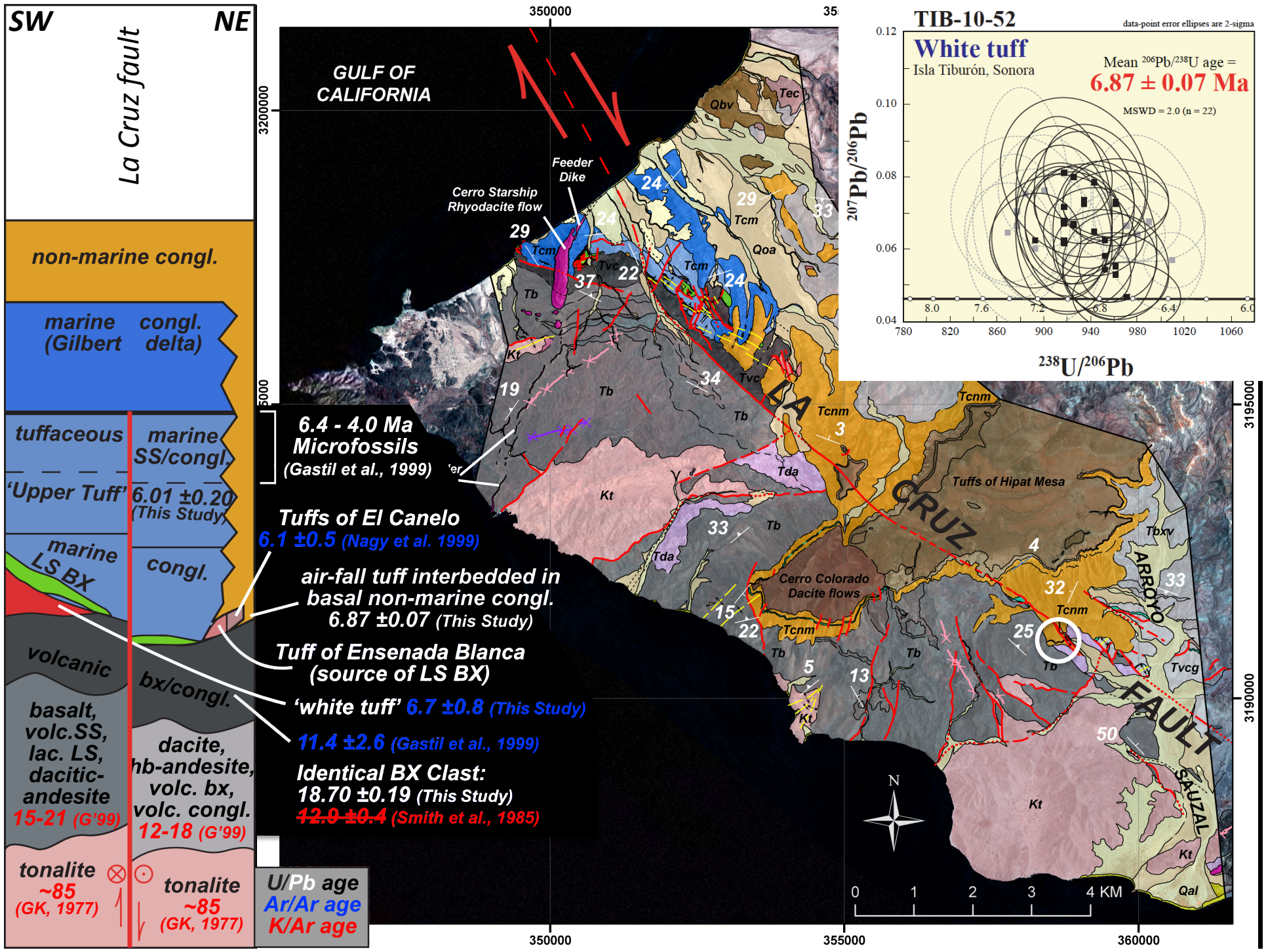


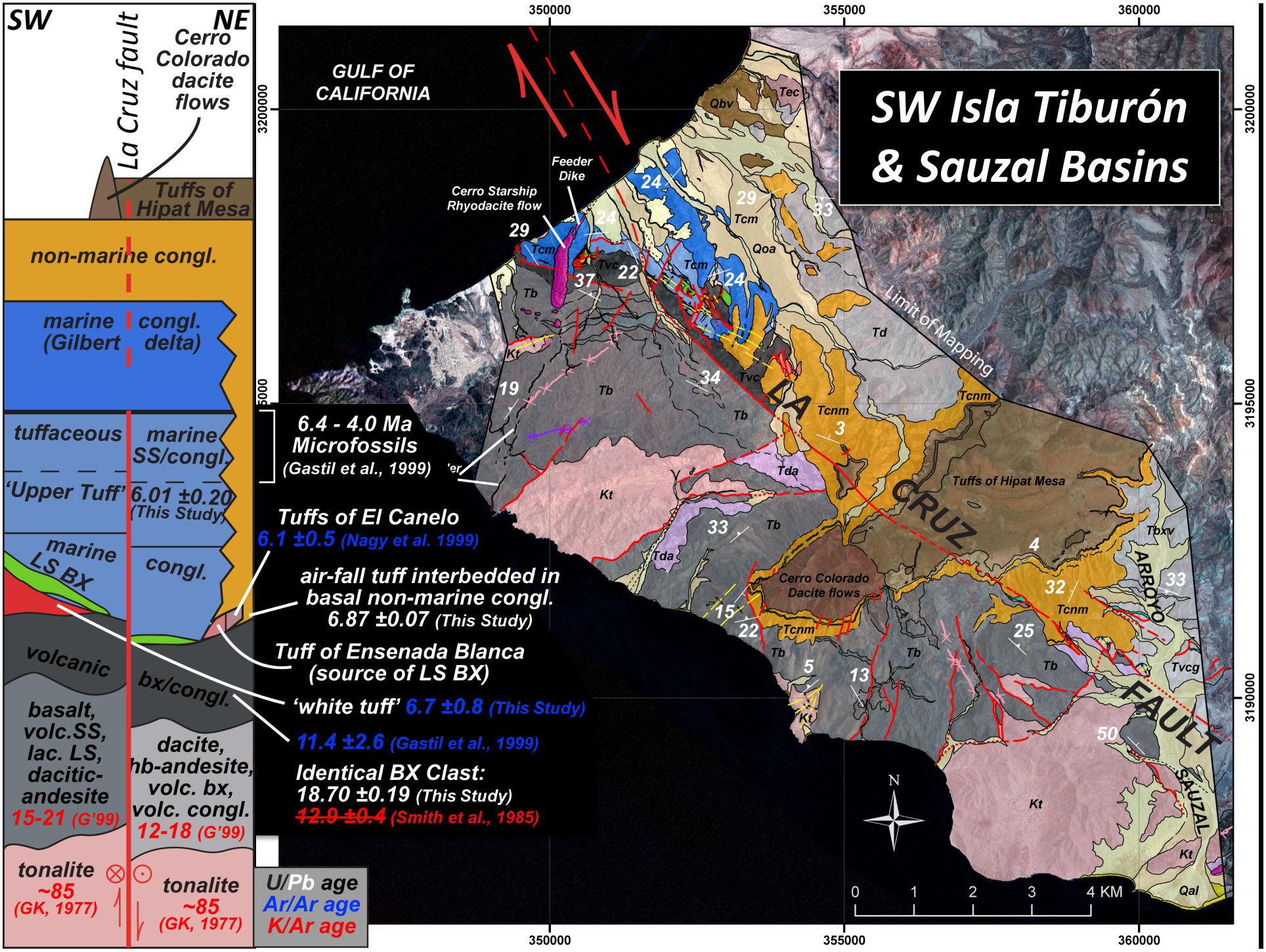
We sampled same exact breccia clast, and obtained an older age of 18.7 Ma. This exposure is from volcanic rx that underlie the marine basin.






SW
NE
La Cruz fault
marine (Gilbert delta)
congl.
tuffaceous
marine SS/congl.
'Upper Tuff'
6.01 ±0.20 (This Study)
marine LS BX
congl.
volcanic
bx/congl.
basalt, volc.SS, lac. LS, dacitic-andesite
15-21 (G'99)
dacite, hb-andesite, volc. bx, volc. congl.
12-18 (G'99)
tonalite ~85 (GK, 1977)
tonalite ~85 (GK, 1977)
6.4 - 4.0 Ma Microfossils (Gastil et al., 1999)
Tuffs of El Canelo
6.1 ±0.5 (Nagy et al. 1999)
Tuff of Ensenada Blanca (source of LS BX)
'white tuff' 6.7 ±0.8 (This Study)
11.4 ±2.6 (Gastil et al., 1999)
Identical BX Clast:
18.70 ±0.19 (This Study)
12.9 ±0.4 (Smith et al., 1985)
U/Pb age
Ar/Ar age
K/Ar age
SW Isla Tiburón & Sauzal Basins
Arroyo 4
Arroyo 3
Arroyo 2
Arroyo 1
Feeder Dike
LA CRUZ FAULT
N
0
0.5
1 KM
350000
351000
352000
353000
354000
3199000
3198000
3197000
3196000
3195000


SW
NE
La Cruz fault
non-marine congl.
marine (Gilbert delta)
congl.
tuffaceous
marine SS/congl.
'Upper Tuff' 6.01 ±0.20 (This Study)
marine LS BX
congl.
volcanic
bx/congl.
basalt, volc.SS, lac. LS, dacitic-andesite 15-21 (G'99)
dacite, hb-andesite, volc. bx, volc. congl. 12-18 (G'99)
tonalite ~85 (GK, 1977)
tonalite ~85 (GK, 1977)
6.4 - 4.0 Ma Microfossils (Gastil et al., 1999)
Tuffs of El Canelo 6.1 ±0.5 (Nagy et al. 1999)
air-fall tuff interbedded in basal non-marine congl. 6.87 ±0.07 (This Study)
Tuff of Ensenada Blanca (source of LS BX)
'white tuff' 6.7 ±0.8 (This Study)
11.4 ±2.6 (Gastil et al., 1999)
Identical BX Clast:
18.70 ±0.19 (This Study)
12.9 ±0.4 (Smith et al., 1985)
U/Pb age
Ar/Ar age
K/Ar age
GULF OF CALIFORNIA
Feeder Dike
Cerro Starship Rhyodacite flow
Tuffs of Hipat Mesa
Cerro Colorado Dacite flows
LA CRUZ
ARROYO SAUZAL FAULT
Qbv
Tec
Tcm
Qoa
Tvc
Tb
Kt
Tda
Tcnm
Tbxv
Tvcg
Qal
N
0 1 2 3 4 KM
350000
355000
360000
3200000
3195000
3190000
TIB-10-52
data-point error ellipses are 2-sigma
White tuff
Isla Tiburón, Sonora
Mean 206Pb/238U age =
6.87 ± 0.07 Ma
MSWD = 2.0 (n = 22)
207Pb/206Pb
238U/206Pb


SW
NE
La Cruz fault
Cerro Colorado dacite flows
Tuffs of Hipat Mesa
non-marine congl.
marine (Gilbert delta)
congl.
tuffaceous marine SS/congl.
'Upper Tuff' 6.01 ±0.20 (This Study)
marine LS BX
congl.
volcanic bx/congl.
basalt, volc.SS, lac. LS, dacitic-andesite 15-21 (G'99)
dacite, hb-andesite, volc. bx, volc. congl. 12-18 (G'99)
tonalite ~85 (GK, 1977)
tonalite ~85 (GK, 1977)
6.4 - 4.0 Ma Microfossils (Gastil et al., 1999)
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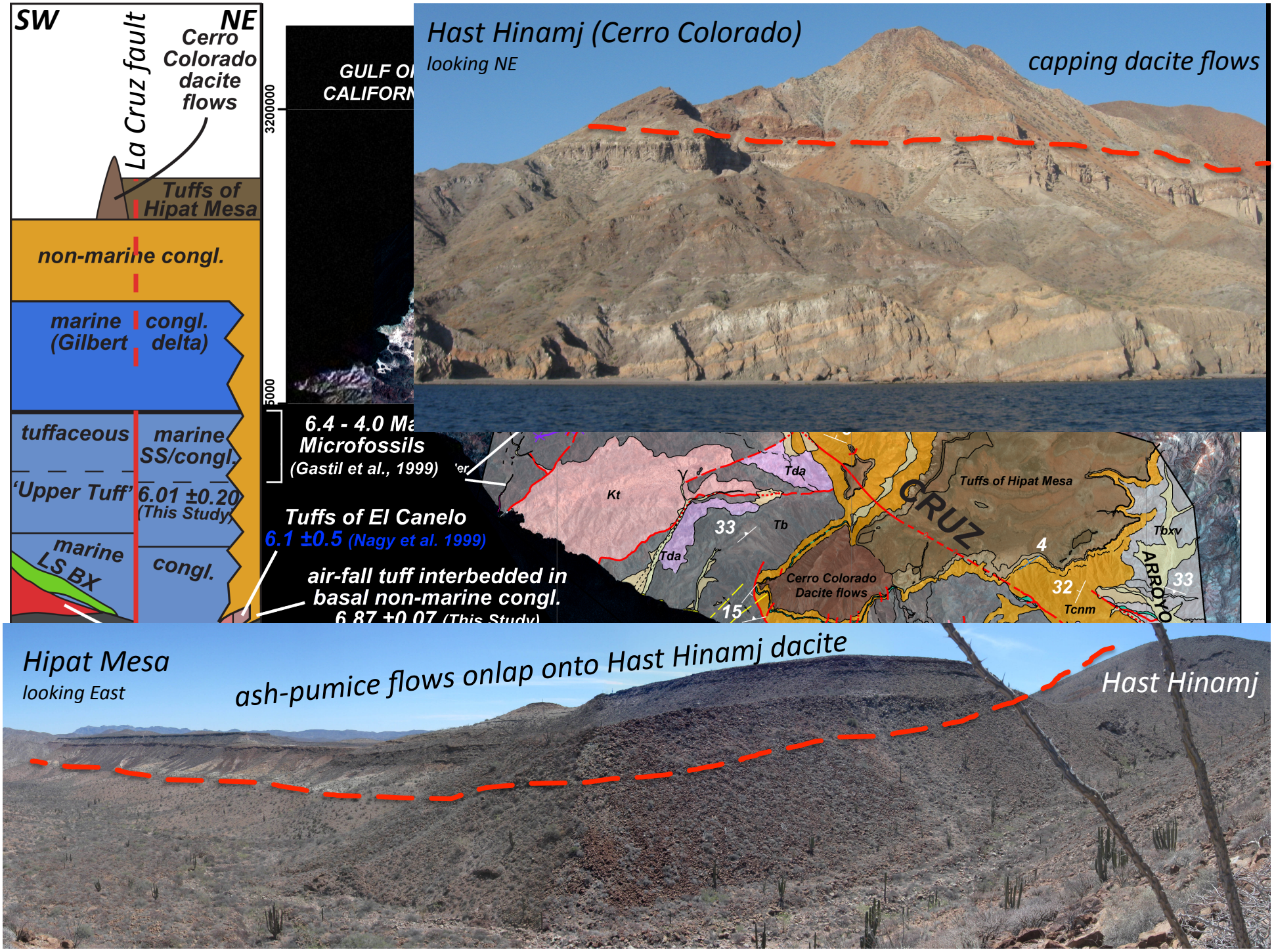
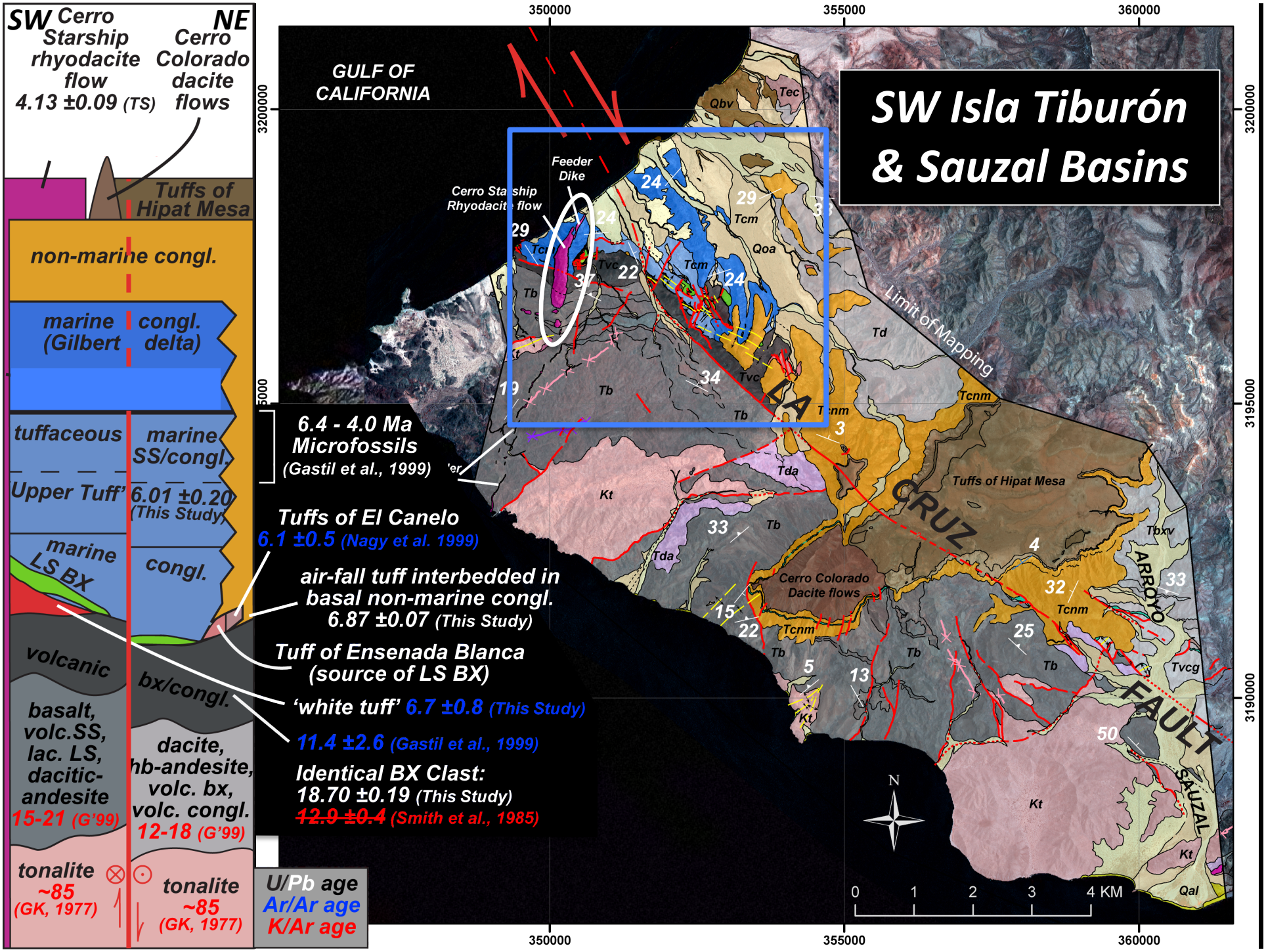
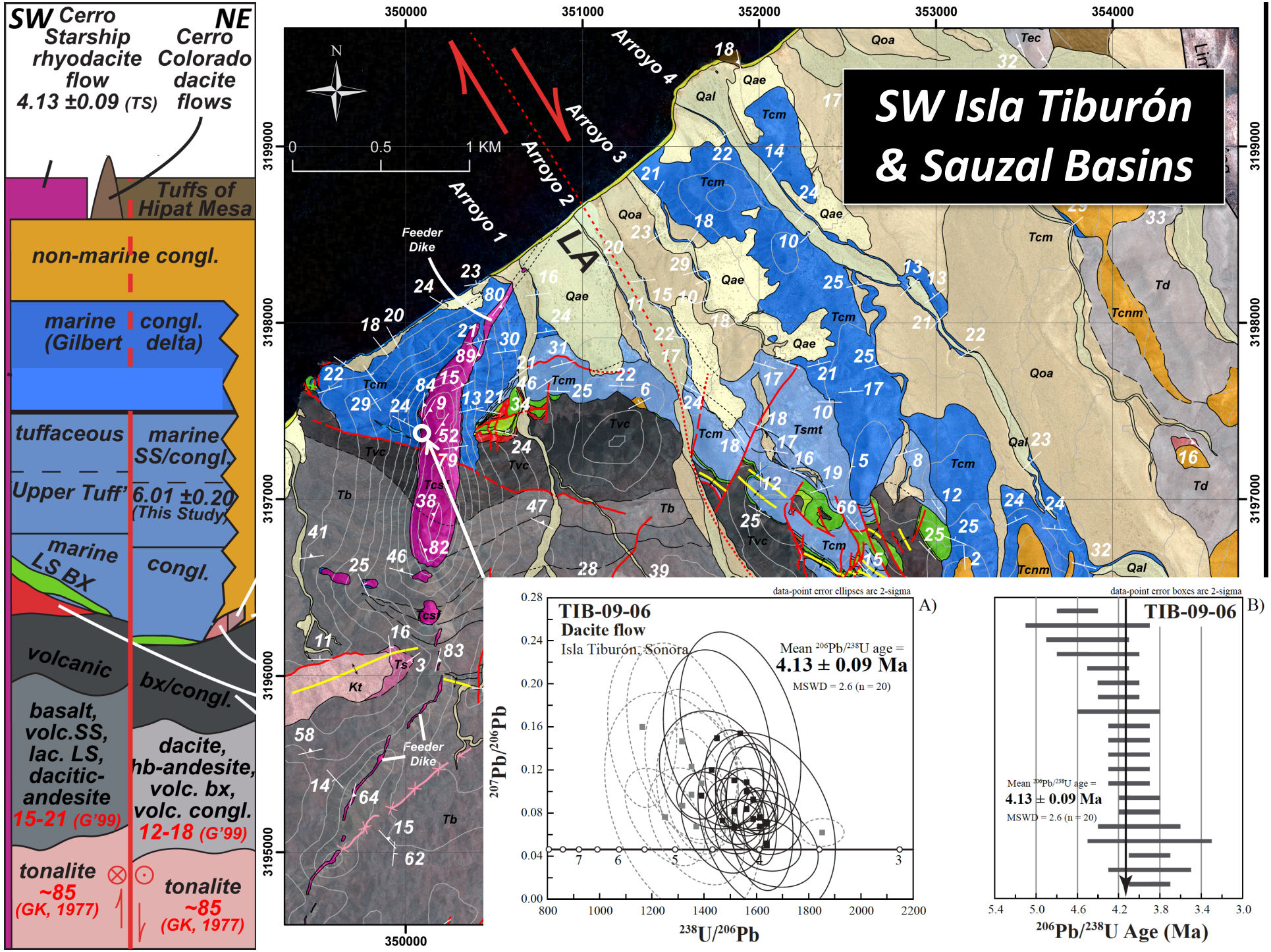
Identical BX Clast:
18.70 ±0.19 (This Study)
12.9 ±0.4 (Smith et al., 1985)
U/Pb age
Ar/Ar age
K/Ar age
GULF OF CALIFORNIA
SW Isla Tiburón & Sauzal Basins
Feeder Dike
Cerro Starship Rhyodacite flow
Limit of Mapping
Cerro Colorado Dacite flows
Tuffs of Hipat Mesa
LA CRUZ FAULT
ARROYO SAUZAL
Qbv
Tec
Qoa
Td
Tcm
Tvc
Tb
Kt
Tda
Tcnm
Tbxv
Tvcg
Qal
350000
355000
360000
3200000
3195000
3190000
0 1 2 3 4 KM
N


SW
NE
La Cruz fault
Cerro Colorado dacite flows
Tuffs of Hipat Mesa
non-marine congl.
marine (Gilbert
congl. delta)
tuffaceous
marine SS/congl.
'Upper Tuff'
6.01 ±0.20 (This Study)
marine LS BX
congl.
3200000
3000
6.4 - 4.0 Ma
Microfossils
(Gastil et al., 1999)
Tuffs of El Canelo
6.1 ±0.5 (Nagy et al. 1999)
air-fall tuff interbedded in basal non-marine congl.
6.87 ±0.07 (This Study)
Hast Hinamj (Cerro Colorado)
looking NE
capping dacite flows
Kt
Tda
Tb
33
Tuffs of Hipat Mesa
CRUZ
4
Tbxv
ARROYO
Cerro Colorado Dacite flows
32
Tcnm
33
15
Hipat Mesa
looking East
ash-pumice flows onlap onto Hast Hinamj dacite
Hast Hinamj



SW Isla Tiburón & Sauzal Basins

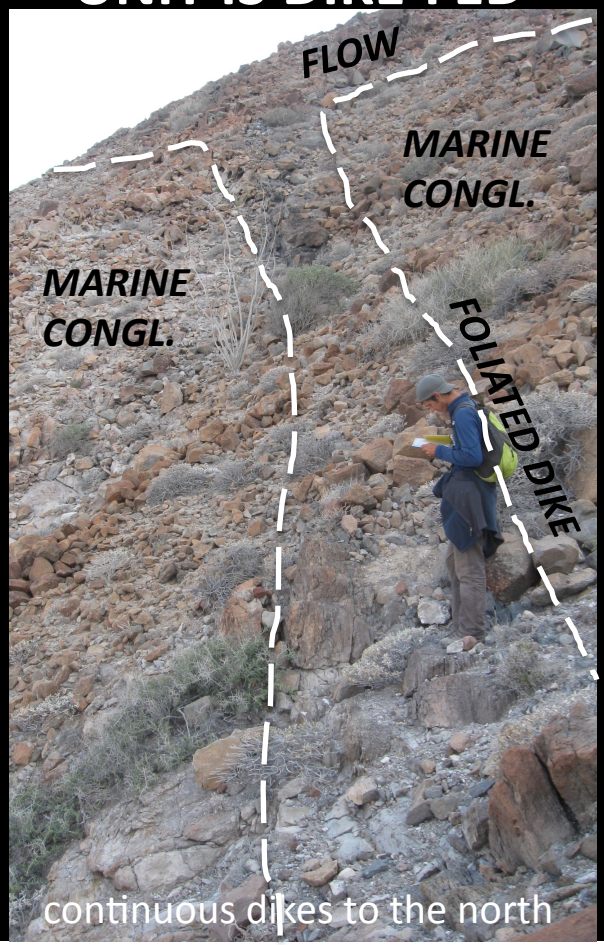

SW Cerro Starship rhyodacite flow 4.13 ±0.09 (TS)
NE Cerro Colorado dacite flows
Tuffs of Hipat Mesa
non-marine congl.
marine (Gilbert delta)
congl.
tuffaceous Upper Tuff'
marine SS/congl.
6.01 ±0.20 (This Study)
marine LS BX
congl.
volcanic
bx/congl.
basalt, volc.SS, lac. LS, dacitic-andesite
15-21 (G'99)
dacite, hb-andesite, volc. bx, volc. congl.
12-18 (G'99)
tonalite ~85 (GK, 1977)
tonalite ~85 (GK, 1977)
SW Isla Tiburón & Sauzal Basins
Arroyo 1
Arroyo 2
Arroyo 3
Arroyo 4
Feeder Dike
Feeder Dike
LA
N
0
0.5
1 KM
350000
351000
352000
353000
354000
3199000
3198000
3197000
3196000
3195000
Qae
Qal
Qoa
Tec
Tcm
Tcnm
Td
Tvc
Tsmt
Tb
Tcs
Ts
Kt
data-point error ellipses are 2-sigma
A)
TIB-09-06
Dacite flow
Isla Tiburón, Sonora
Mean 206Pb/238U age =
4.13 ± 0.09 Ma
MSWD = 2.6 (n = 20)
207Pb/206Pb
238U/206Pb
data-point error boxes are 2-sigma
B)
TIB-09-06
Mean 206Pb/238U age =
4.13 ± 0.09 Ma
MSWD = 2.6 (n = 20)
206Pb/238U Age (Ma)

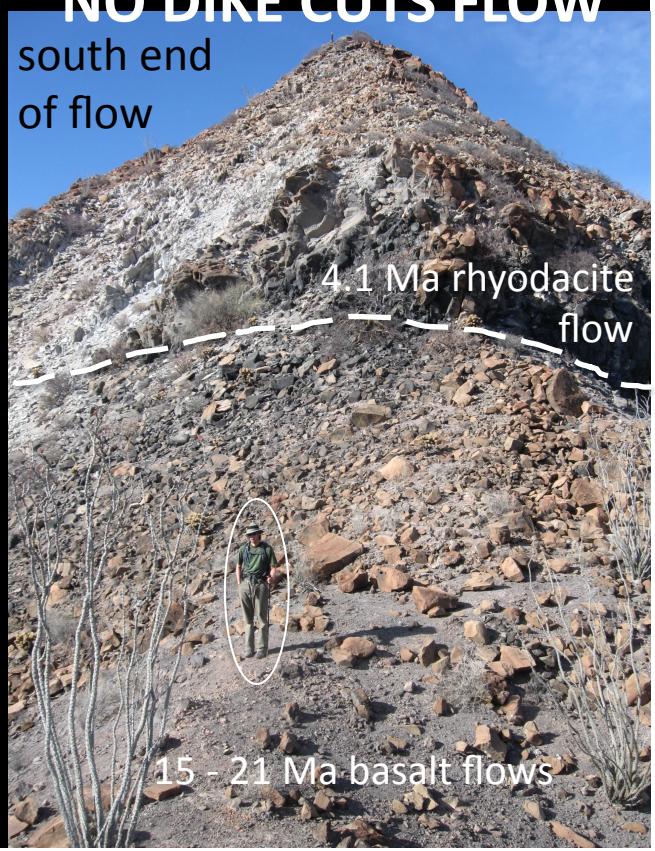
Hast Pitzcal (Cerro Starship) Rhyodacite flow

UNIT IS DIKE-FED

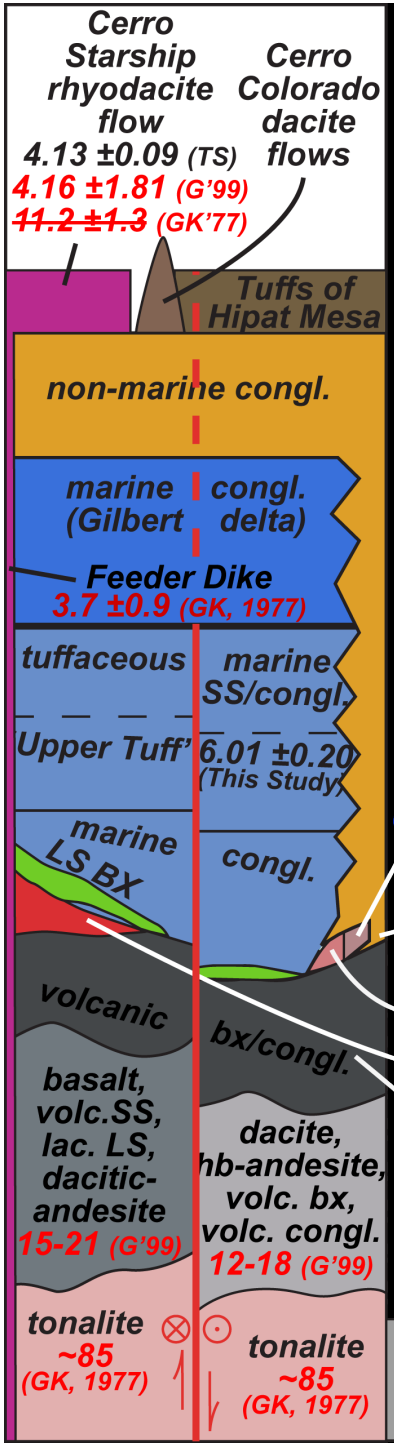
NO DIKE CUTS FLOW

NOT AN ASH-FLOW TUFF





Summary



EARLIEST MARINE ROCKS ON ISLA TIBURON

6.4 - 4.0 Ma Microfossils (Gastil et al., 1999)

Tuffs of El Canelo
6.1 ±0.5 (Nagy et al. 1999)

air-fall tuff interbedded in basal non-marine congl.
6.87 ±0.07 (This Study)

Tuff of Ensenada Blanca (source of LS BX)

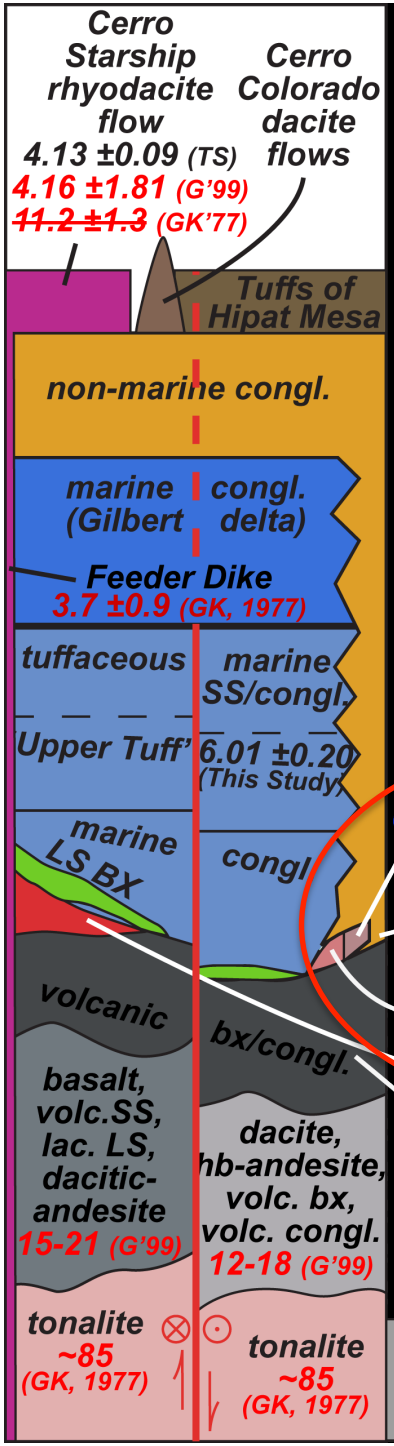
'white tuff' 6.7 ±0.8 (This Study)

11.4 ±2.6 (Gastil et al., 1999)

Identical BX Clast:
18.70 ±0.19 (This Study)
12.9 ±0.4 (Smith et al., 1985)

U/Pb age
Ar/Ar age
K/Ar age

Summary



EARLIEST MARINE ROCKS ON ISLA TIBURON

Maximum Age = ~ 6.8 Ma

6.4 - 4.0 Ma Microfossils (Gastil et al., 1999)

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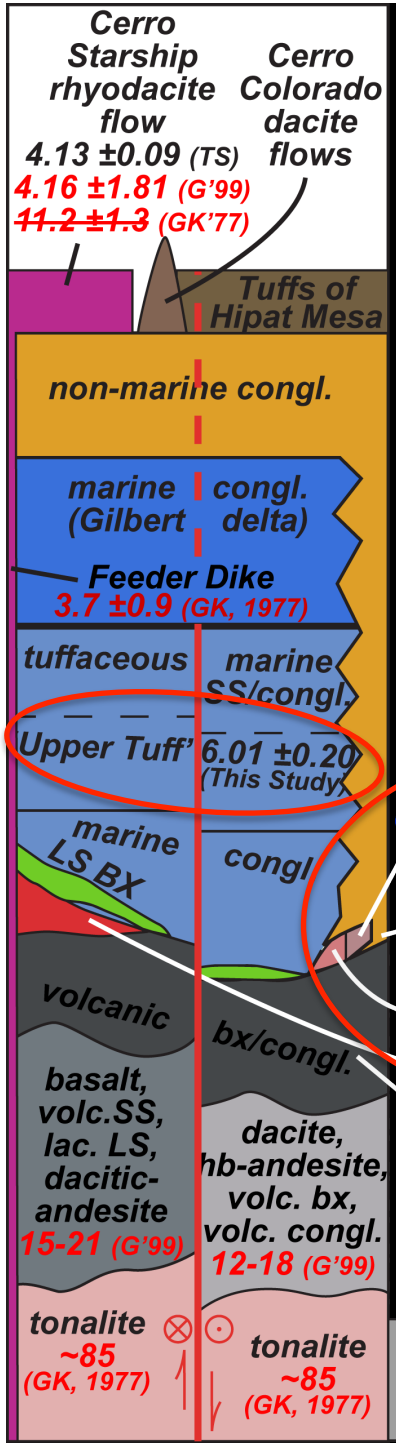
Summary



Minimum Age = ~ 6.0 Ma

EARLIEST MARINE ROCKS ON ISLA TIBURON

Maximum Age = ~ 6.8 Ma

6.4 - 4.0 Ma Microfossils (Gastil et al., 1999)

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11.4 ±2.6 (Gastil et al., 1999)

Identical BX Clast:
18.70 ±0.19 (This Study)
12.9 ±0.4 (Smith et al., 1985)

Summary

Basin inactive by ~ 4.1 Ma

Minimum Age = ~ 6.0 Ma

EARLIEST MARINE ROCKS ON ISLA TIBURON

Maximum Age = ~ 6.8 Ma

6.4 - 4.0 Ma Microfossils (Gastil et al., 1999)

Tuffs of El Canelo
6.1 ±0.5 (Nagy et al. 1999)

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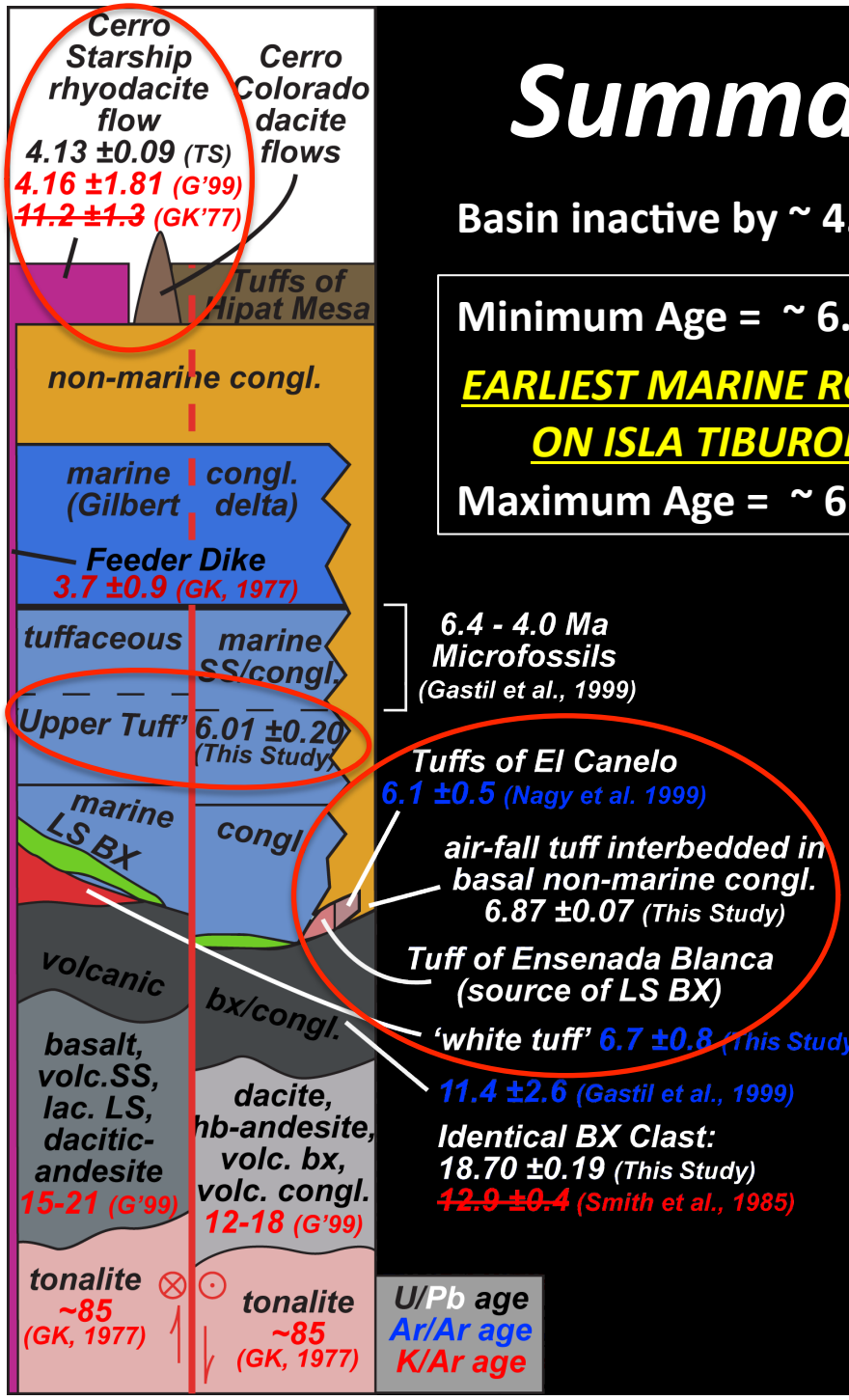
Summary

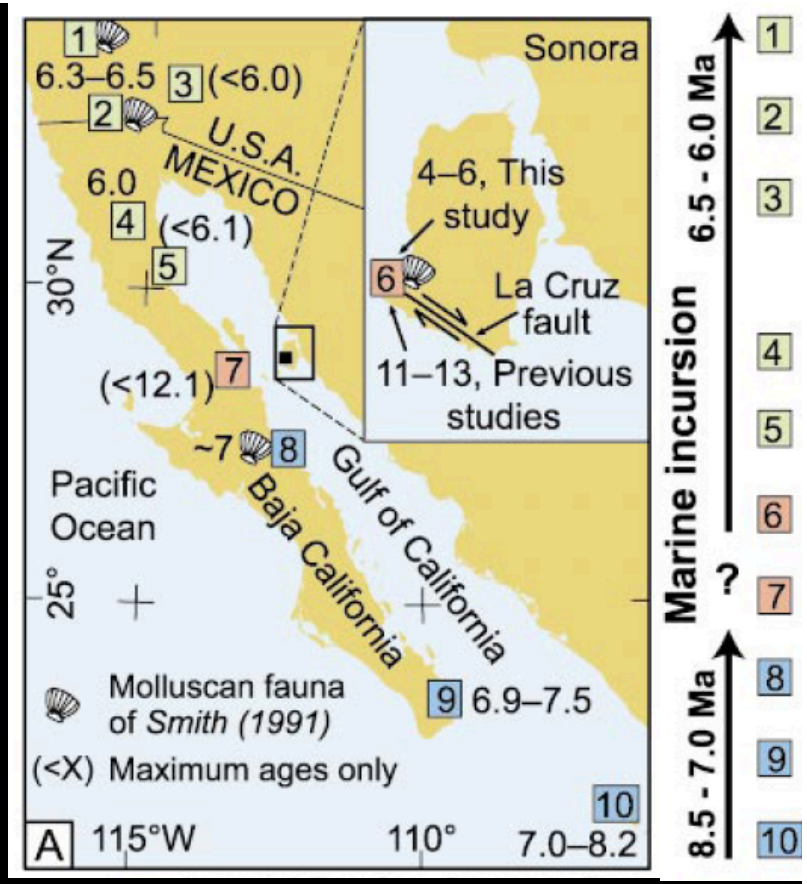
Basin inactive by ~ 4.1 Ma

Minimum Age = ~ 6.0 Ma

EARLIEST MARINE ROCKS ON ISLA TIBURON

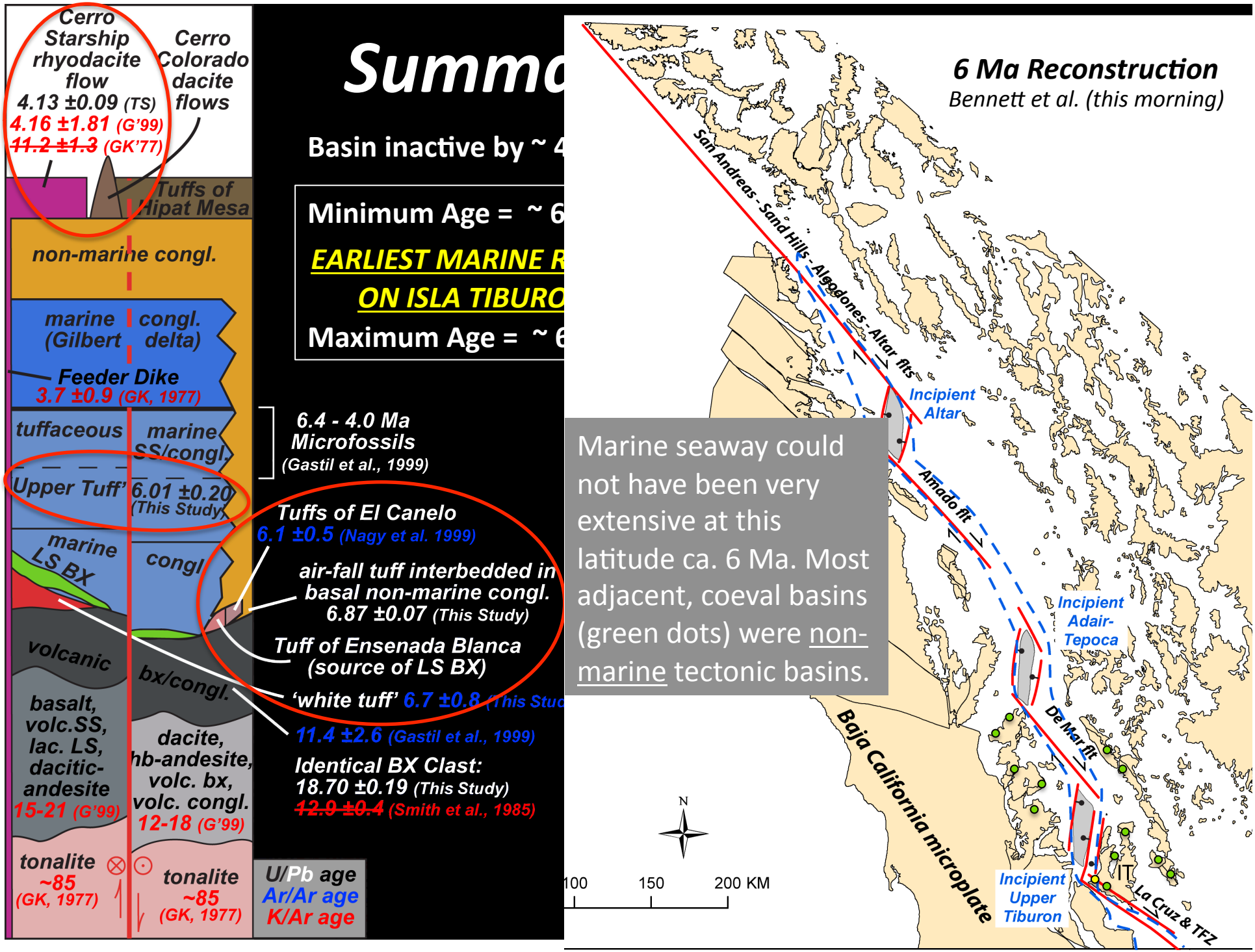
Maximum Age = ~ 6.8 Ma





Oskin & Stock (2003)

Agrees with published models of synchronous marine incursion and plate boundary-scale strain localization ca. 6.5 - 6.0 Ma


Cerro Starship rhyodacite flow
4.13 ±0.09 (TS)
4.16 ±1.81 (G'99)
11.2 ±1.3 (GK'77)
Cerro Colorado dacite flows
Tuffs of Hipat Mesa
non-marine congl.
marine (Gilbert delta)
congl.
Feeder Dike
3.7 ±0.9 (GK, 1977)
tuffaceous
marine SS/congl.
Upper Tuff' 6.01 ±0.20 (This Study)
marine LS BX
congl
volcanic
bx/congl.
basalt, volc.SS, lac. LS, dacitic-andesite
15-21 (G'99)
dacite, hb-andesite, volc. bx, volc. congl.
12-18 (G'99)
tonalite ~85 (GK, 1977)
tonalite ~85 (GK, 1977)
Summa
Basin inactive by ~ 4
Minimum Age = ~ 6
EARLIEST MARINE R
ON ISLA TIBURO
Maximum Age = ~ 6
6.4 - 4.0 Ma Microfossils (Gastil et al., 1999)
Tuffs of El Canelo
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Identical BX Clast:
18.70 ±0.19 (This Study)
12.9 ±0.4 (Smith et al., 1985)
U/Pb age
Ar/Ar age
K/Ar age
6 Ma Reconstruction
Bennett et al. (this morning)
San Andreas - Sand Hills - Algodones - Altar flts
Incipient Altar
Amado flt
Incipient Adair-Tepoca
De Mar flt
Baja California microplate
Incipient Upper Tiburon
La Cruz & TFZ
IT
N
100
150
200 KM
Marine seaway could not have been very extensive at this latitude ca. 6 Ma. Most adjacent, coeval basins (green dots) were non-marine tectonic basins.

Acknowledgments

Tappa
Jordan Ford
Nick Buckmaster
Molly Keogh
Ernesto Molina, family, and Seri tribe
Prescott College - Kino Bay Center