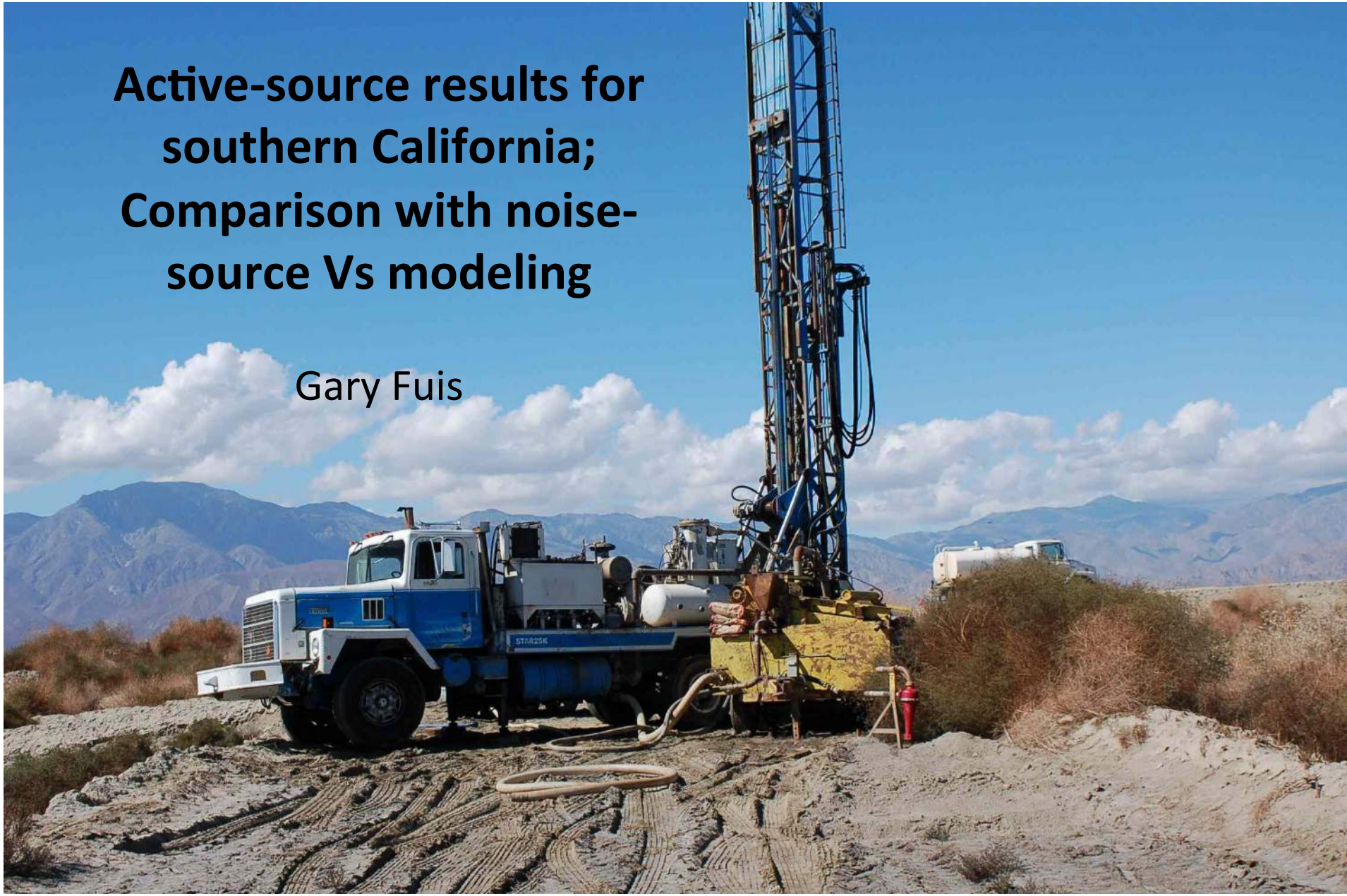
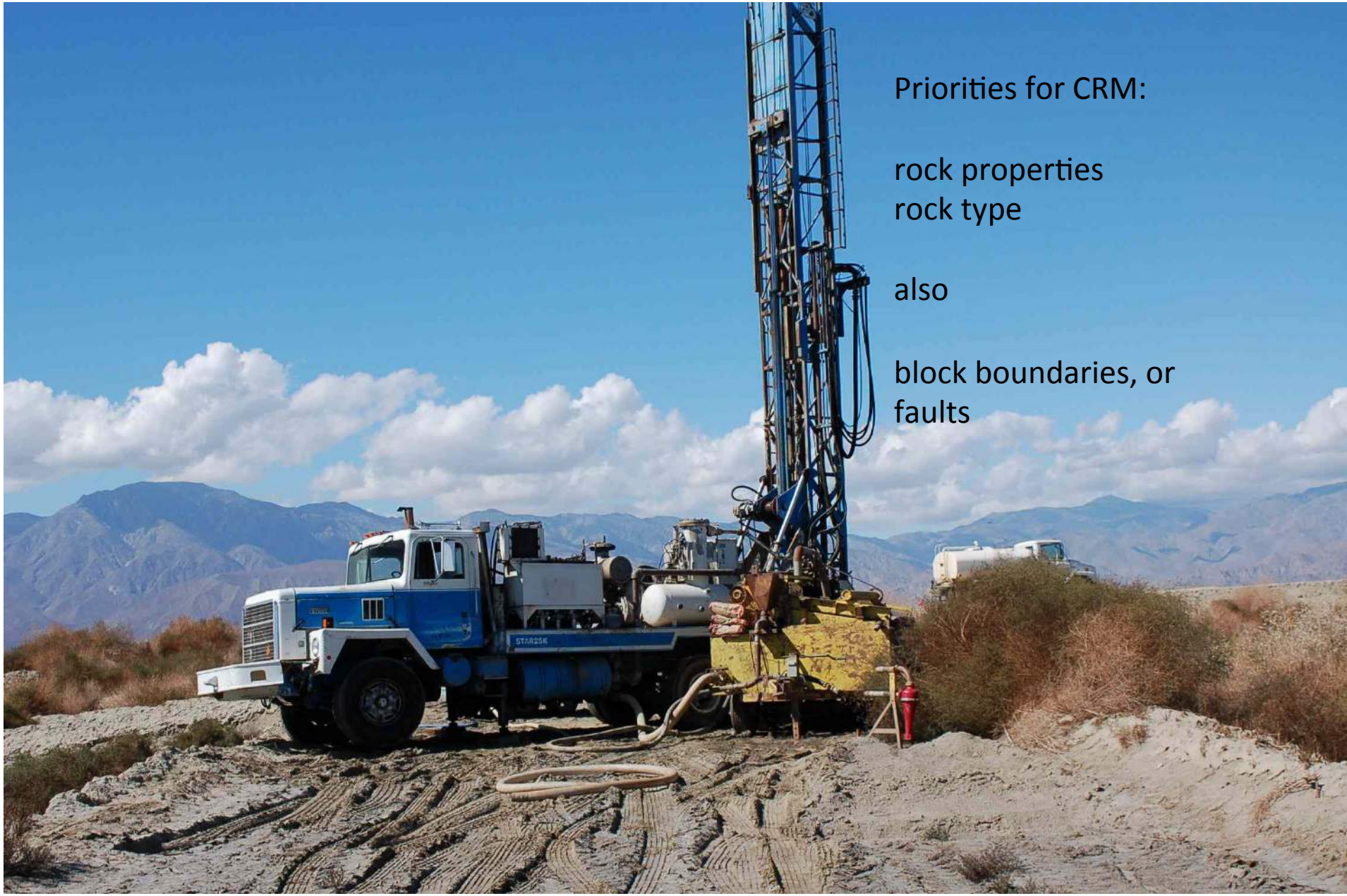
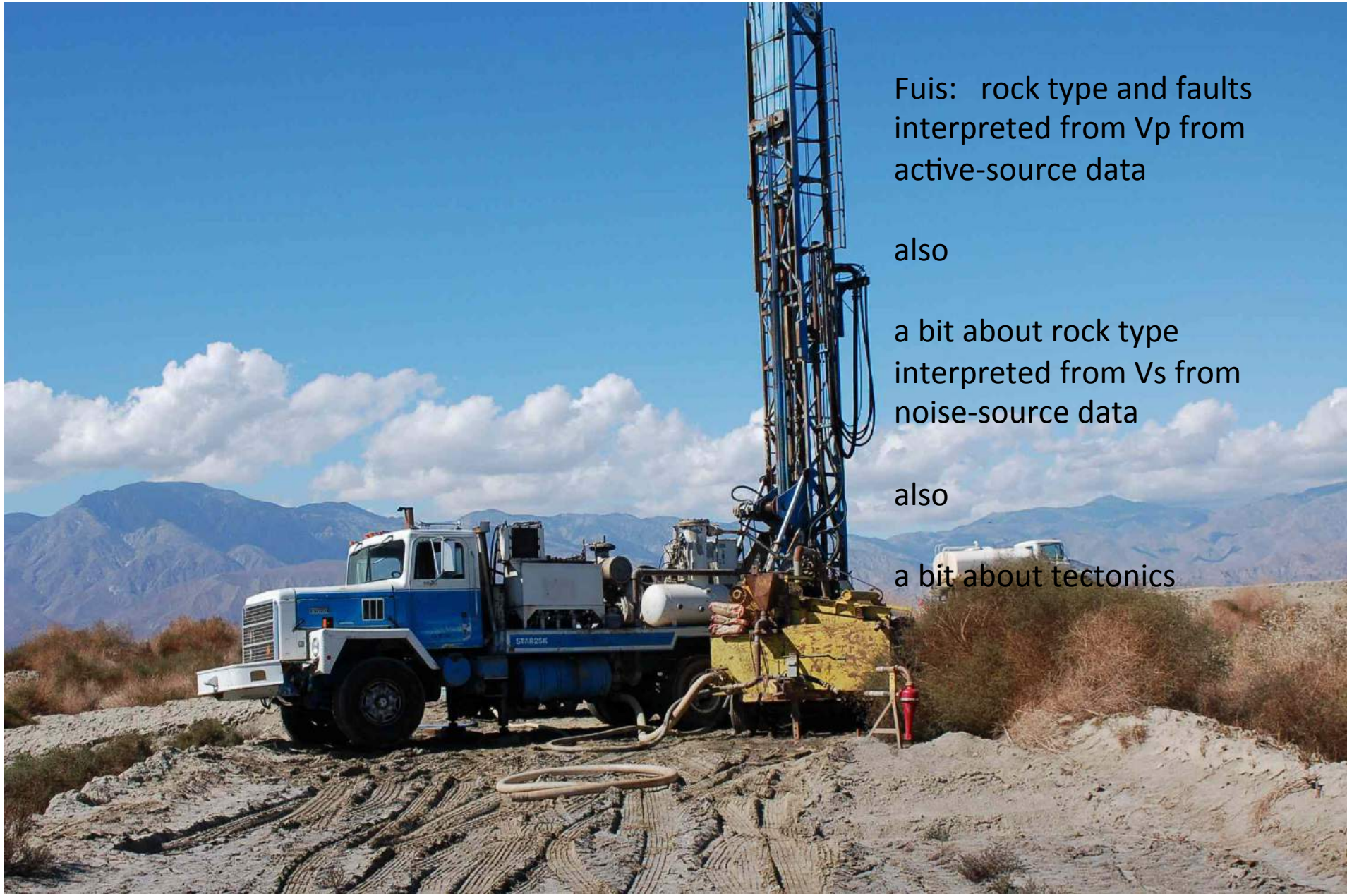
Active-source results for southern California; Comparison with noise-source Vs modeling

Gary Fuis




Priorities for CRM:
rock properties
rock type
also
block boundaries, or
faults


In this session we will focus on
seismic properties
also
density and
magnetic susceptibility



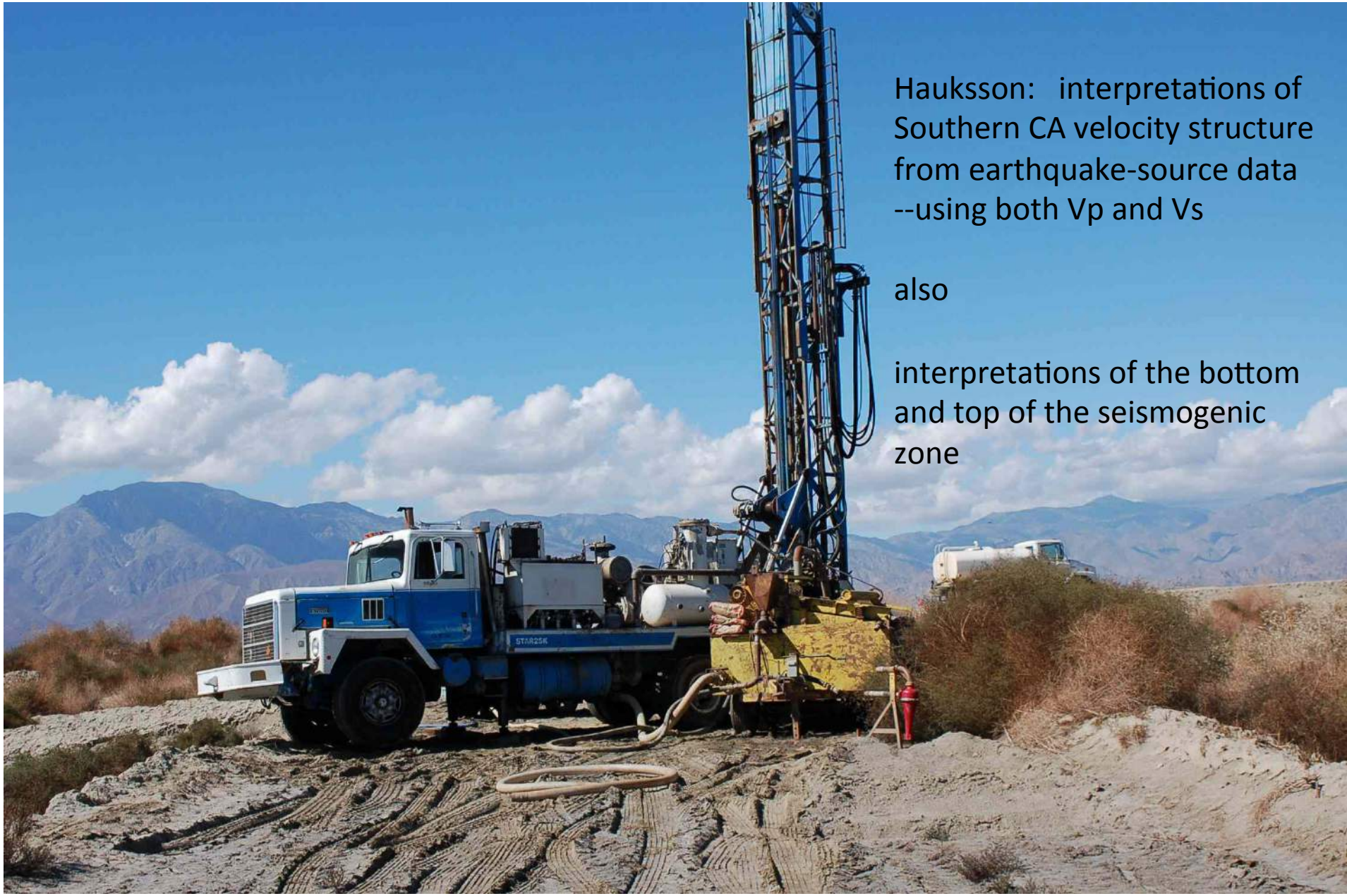
Fuis: rock type and faults interpreted from Vp from active-source data

also

a bit about rock type interpreted from Vs from noise-source data

also

a bit about tectonics



Hauksson: interpretations of Southern CA velocity structure from earthquake-source data --using both Vp and Vs

also

interpretations of the bottom and top of the seismogenic zone

Catchings: Vp, Vs, Vp/Vs from shallow active-source data

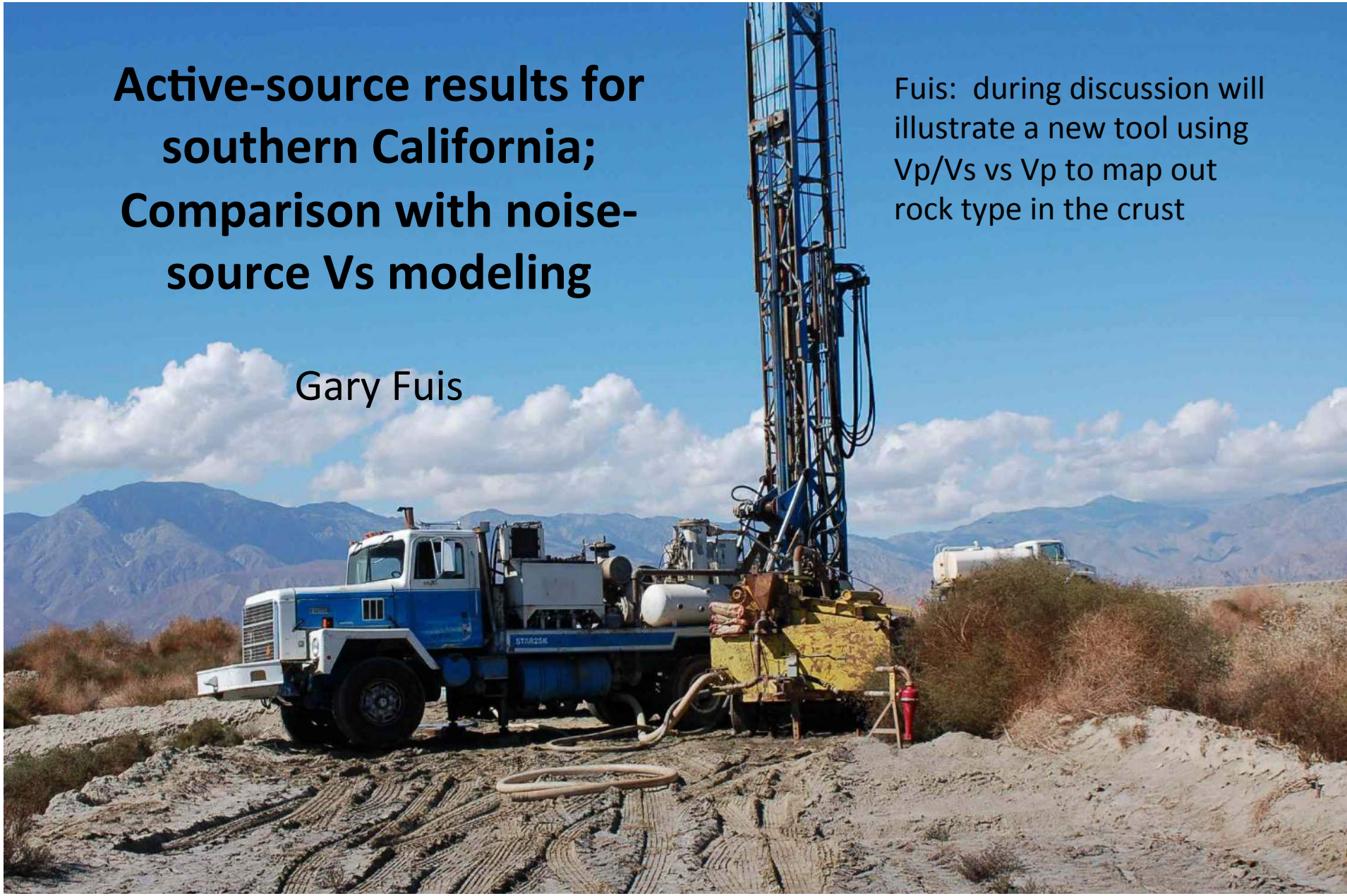
also

example of use of Vp, Vs, and Vp/Vs from Koyna Dam area, India

Active-source results for southern California; Comparison with noise-source Vs modeling

Gary Fuis

Fuis: during discussion will illustrate a new tool using Vp/Vs vs Vp to map out rock type in the crust



Comparison of Seismic-Imaging Methods

Active-Source Methods

Advantages

Detailed imaging of near-surface (velocities)
Reflection imaging
Uniform coverage (by design)

Disadvantages

Resolution diminishes rapidly with depth
Commonly only 2-D
Commonly only Vp
Expensive (to scientists)

Earthquake-source Methods

Advantages

Coverage of whole crust and mantle
3-D
Includes Vp and Vs
Cheap (to scientists)

Disadvantages

No resolution of near surface (no accurate velocities)
No reflections
Non-uniform source coverage

Comparison of Seismic-Imaging Methods (cont.)

Noise-source Methods

Advantages

Coverage of whole crust and mantle
3-D
Uniform source coverage
Cheap (to scientists)

Disadvantages

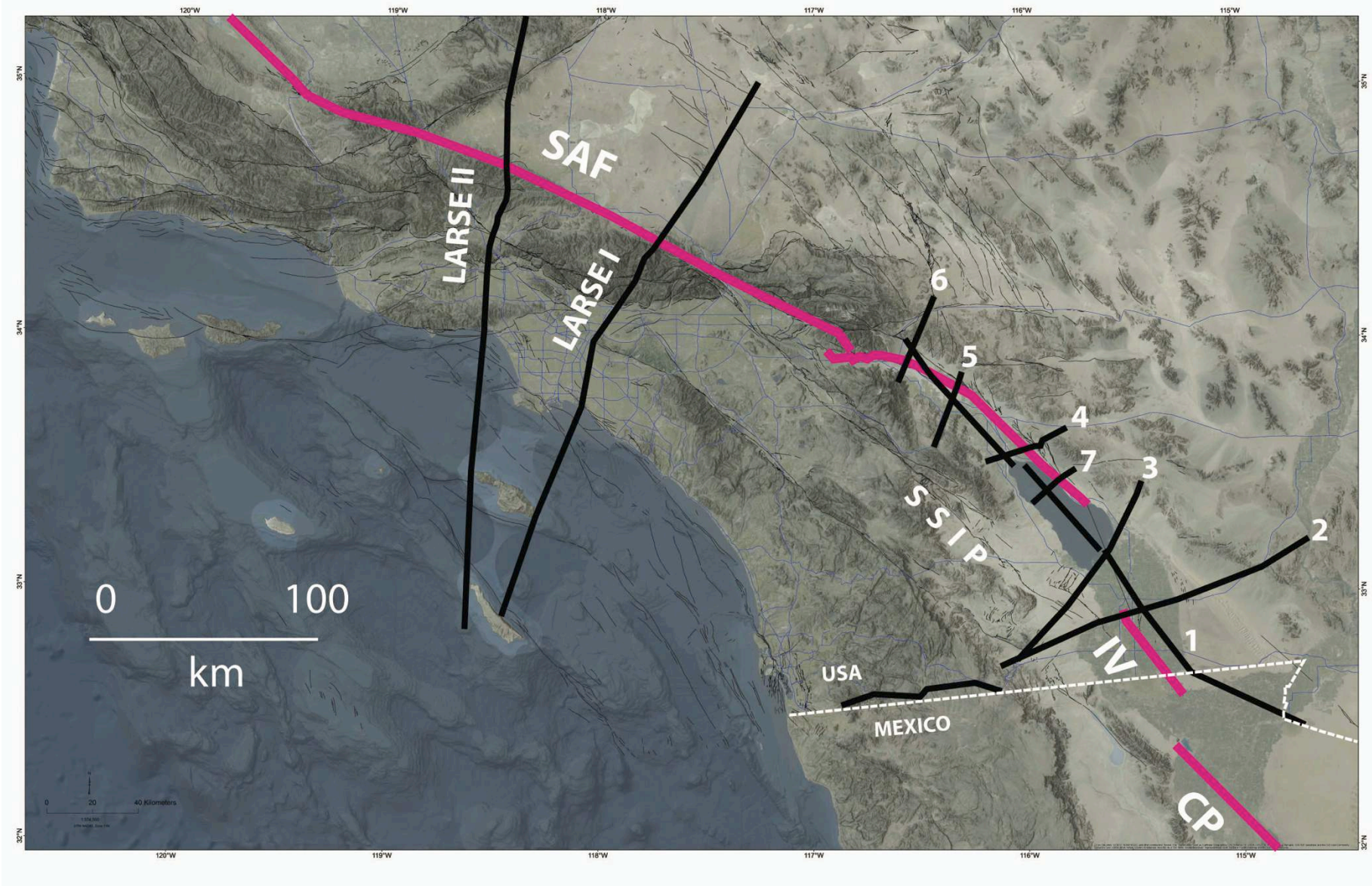
No reflections
Vs only

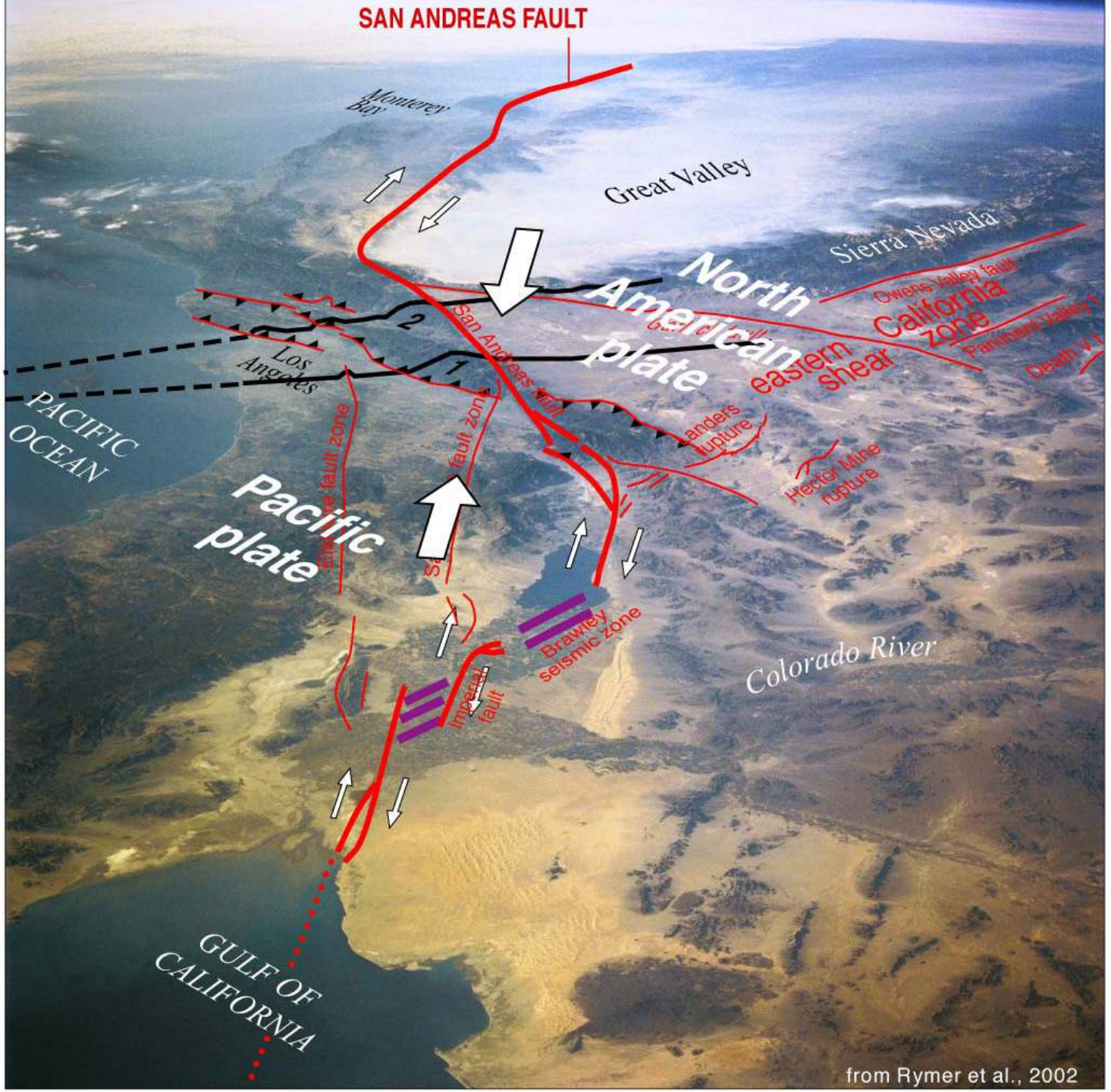
Comparison of Seismic-Imaging Methods (cont.)

Resolution for all methods depends on station and source spacing

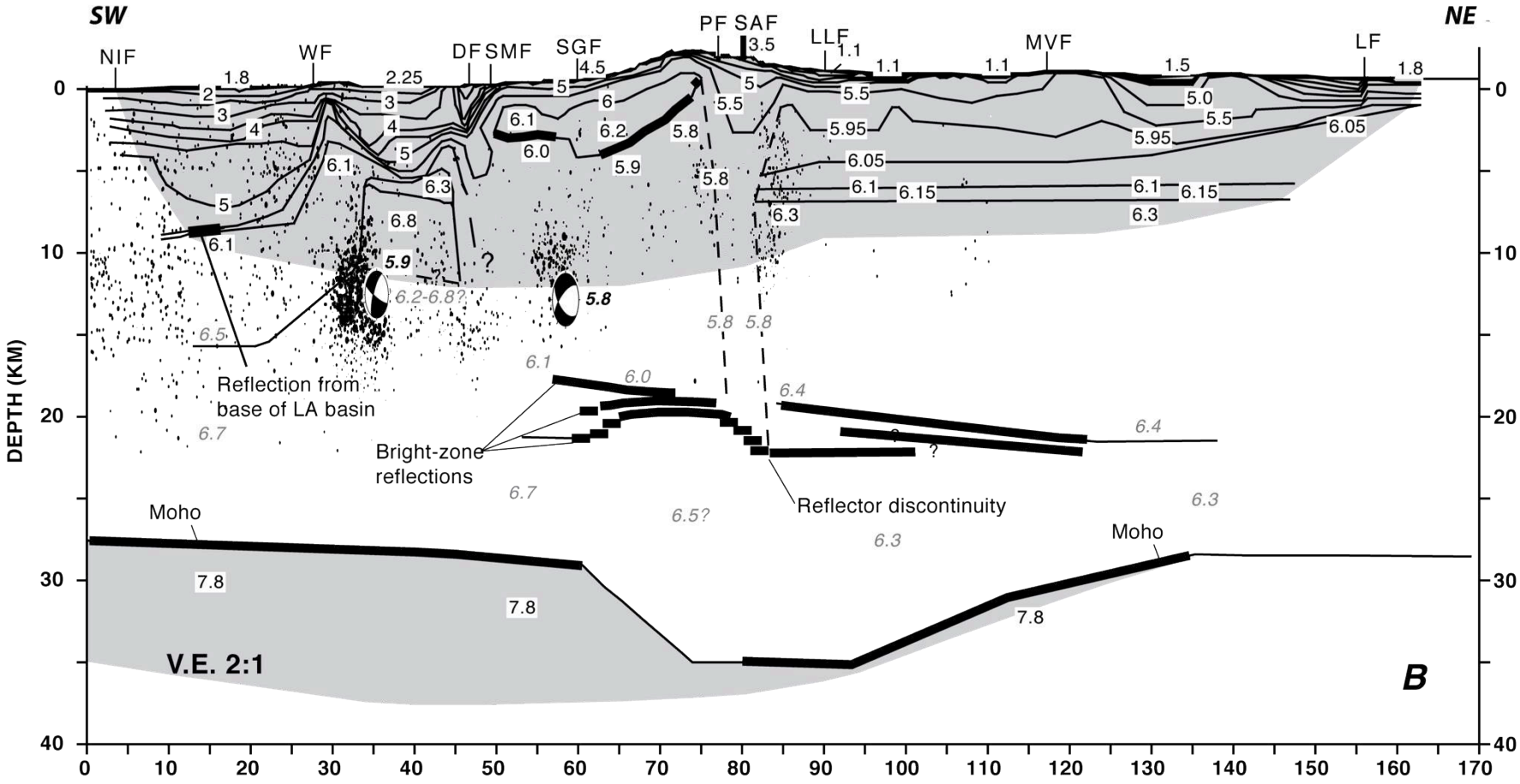
The 3 methods are complementary and all are necessary for a complete picture

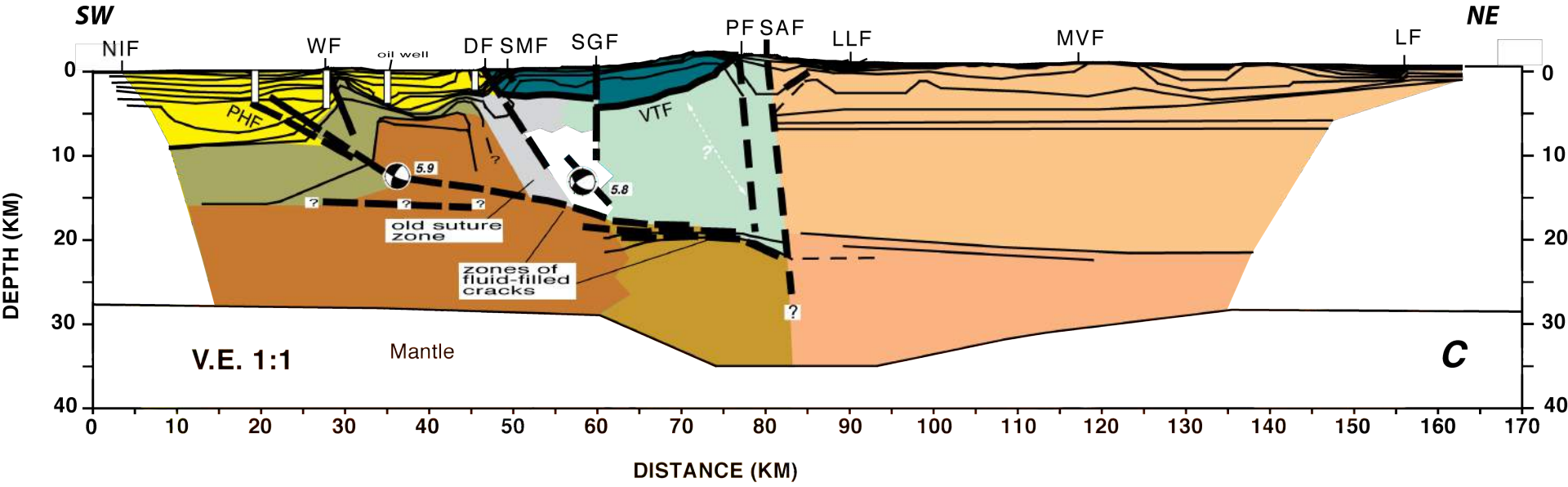
Vp


120°W
119°W
118°W
117°W
116°W
115°W
35°N
34°N
33°N
32°N
SAF
LARSE II
LARSE I
6
5
4
7
3
2
1
SSIP
IV
CP
USA
MEXICO
0
100
km
0
20
40 Kilometers


SAN ANDREAS FAULT
Monterey Bay
Great Valley
Sierra Nevada
North American plate
Owens Valley fault
California zone
Panamint Valley f
Death Val
eastern shear
San Andreas fault
2
1
Los Angeles
PACIFIC OCEAN
anders rupture
Hector Mine rupture
Pacific plate
fault zone
Brawley seismic zone
Imperial fault
Colorado River
GULF OF CALIFORNIA
from Rymer et al., 2002

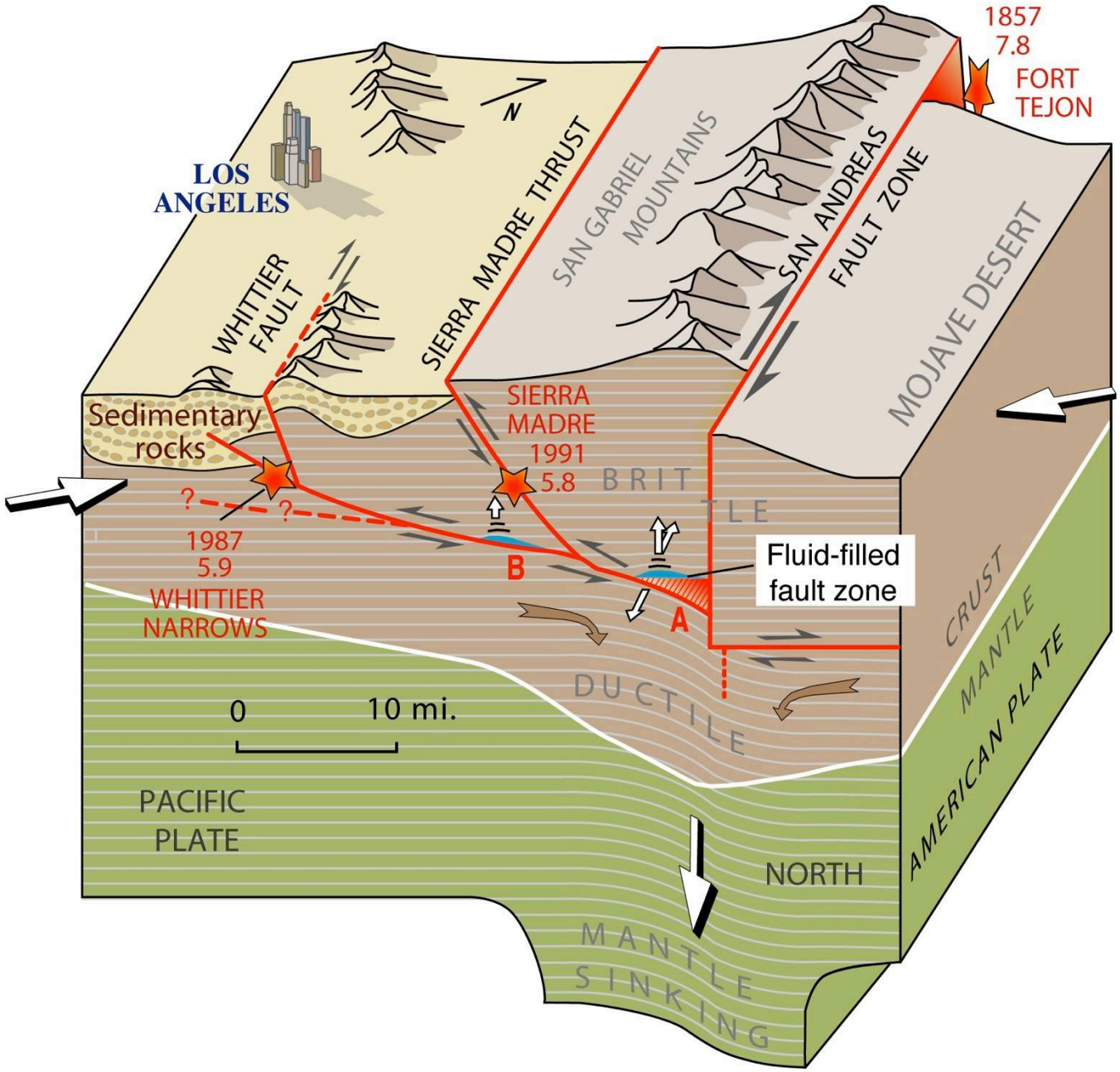

GARLOCK FAULT
Line 2
Mojave
Dry lakes
N
SAN ANDREAS FAULT
Desert
Line 1
ZONE
Central
Santa Clarita Valley
6.7b
San Transverse Ranges
Gabriel Mts
Santa Susana Mts
SSF
GABRIEL FAULT
SF
MHF
NHF
SMFZ
6.7a
5.8
San Fernando Valley
VF
RF
San Gabriel Valley
Santa Monica Mts
HF
SMFZ
MCF
SMoF
Los Angeles
5.9
Santa Monica
Puente Hills
34°N
NEWPORT—INGLEWOOD FAULT
Los Angeles Basin
WHITTIER FAULT
Santa Monica Bay
Peninsular Ranges
Pacific Ocean
Seal Beach
6.3
118°W
California
Area of map
0 10 20 30 40 50 60 70
km

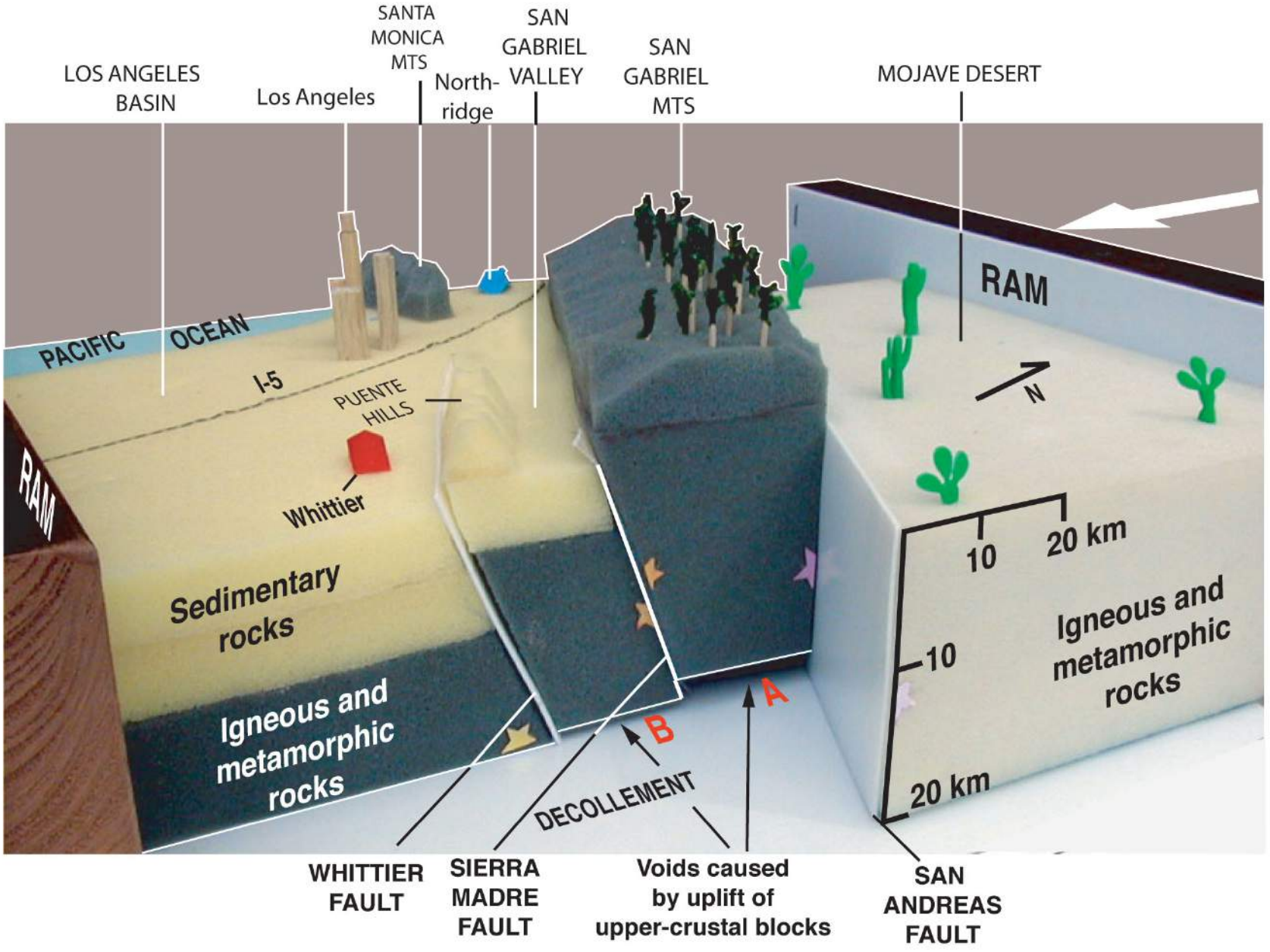

SW
NE
NIF
WF
DF
SMF
SGF
PF
SAF
LLF
MVF
LF
DEPTH (KM)
Reflection from base of LA basin
Bright-zone reflections
Reflector discontinuity
Moho
Moho
V.E. 2:1
B

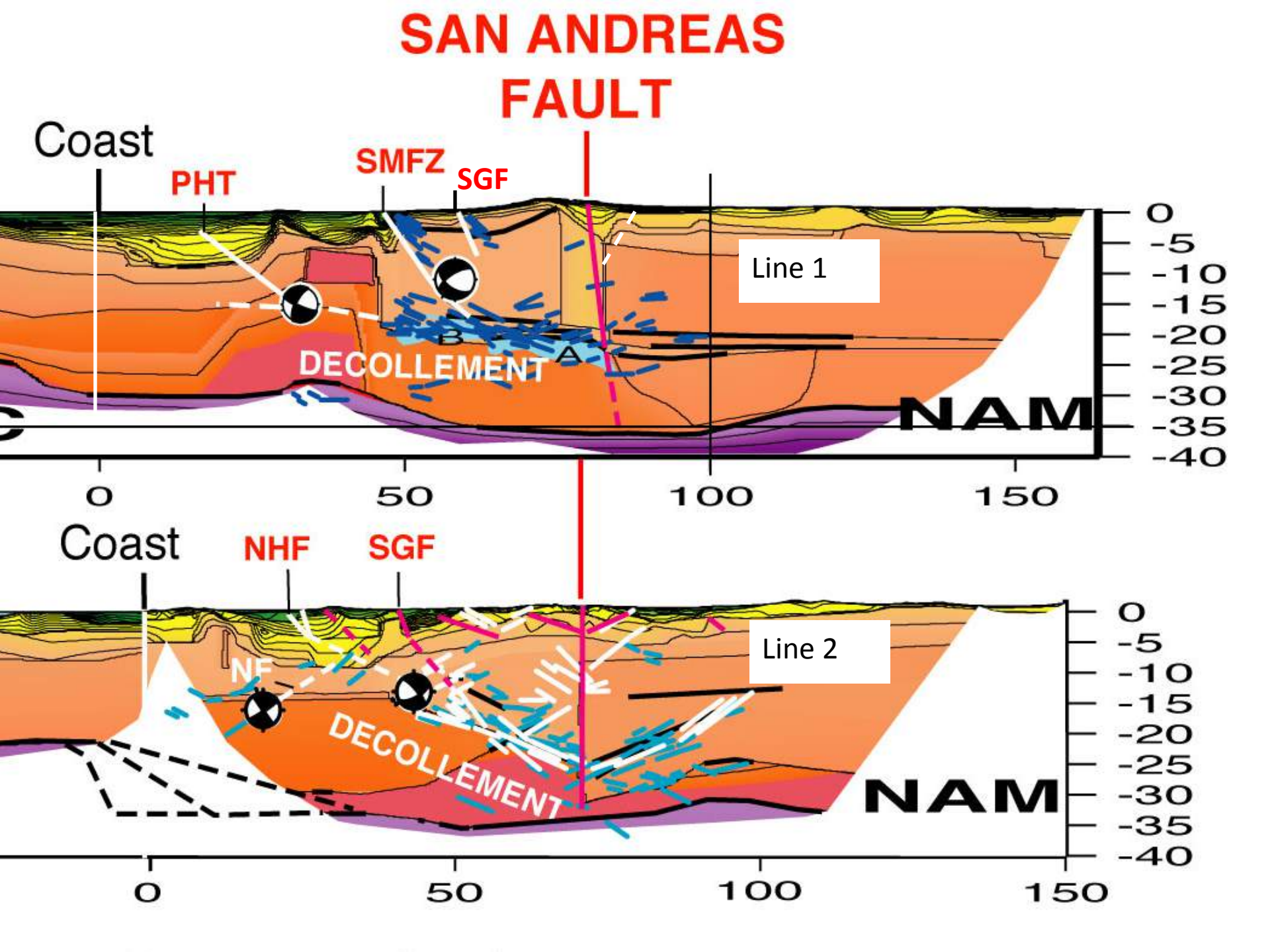


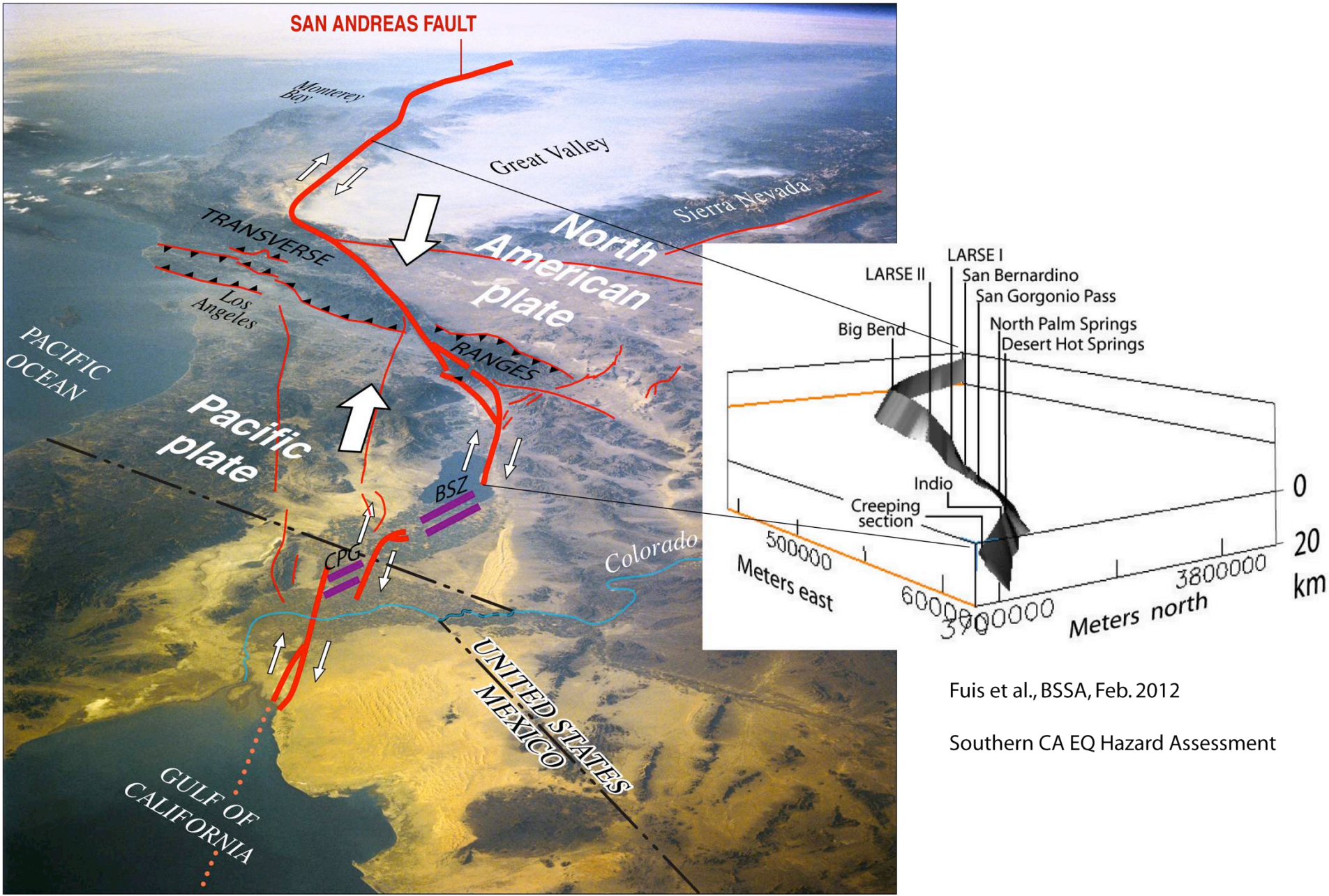
ROCKS

- Cenozoic sedimentary and volcanic rocks
- Mesozoic and older batholithic and metamorphic rocks of Mojave Desert
- Mesozoic batholithic and metamorphic rocks of Peninsular Ranges; brown, mafic rocks
- Pelona Schist (lower plate of San Gabriel Mountains)
- Mylonites and igneous and metamorphic rocks of upper plate of San Gabriel Mountains
- Lower crustal rocks of Mojave Desert
- Lower crustal rocks of Peninsular Ranges; darker brown, mafic(?) rocks
- Undivided rocks of low velocity


1857
7.8
FORT
TEJON
LOS
ANGELES
N
WHITTIER
FAULT
SIERRA MADRE THRUST
SAN GABRIEL
MOUNTAINS
SAN ANDREAS
FAULT ZONE
MOJAVE DESERT
Sedimentary
rocks
SIERRA
MADRE
1991
5.8
BRITTLE
?
?
1987
5.9
WHITTIER
NARROWS
B
A
Fluid-filled
fault zone
CRUST
MANTLE
AMERICAN PLATE
0
10 mi.
DUCTILE
PACIFIC
PLATE
NORTH
MANTLE
SINKING

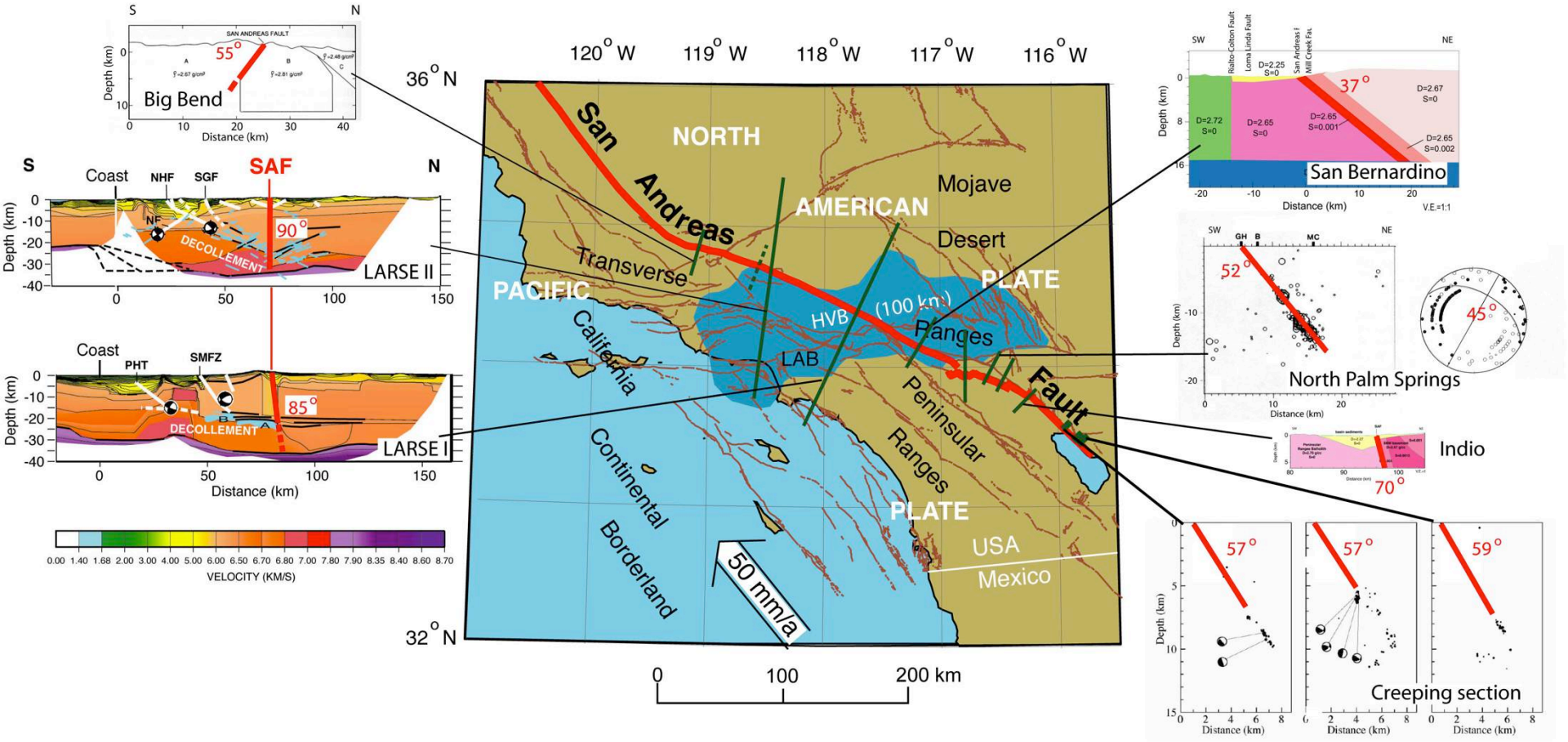

LOS ANGELES BASIN
Los Angeles
SANTA MONICA MTS
North-ridge
SAN GABRIEL VALLEY
SAN GABRIEL MTS
MOJAVE DESERT
PACIFIC OCEAN
I-5
PUENTE HILLS
Whittier
RAM
RAM
N
Sedimentary rocks
Igneous and metamorphic rocks
10
20 km
10
20 km
Igneous and metamorphic rocks
A
B
DECOLLEMENT
WHITTIER FAULT
SIERRA MADRE FAULT
Voids caused by uplift of upper-crustal blocks
SAN ANDREAS FAULT

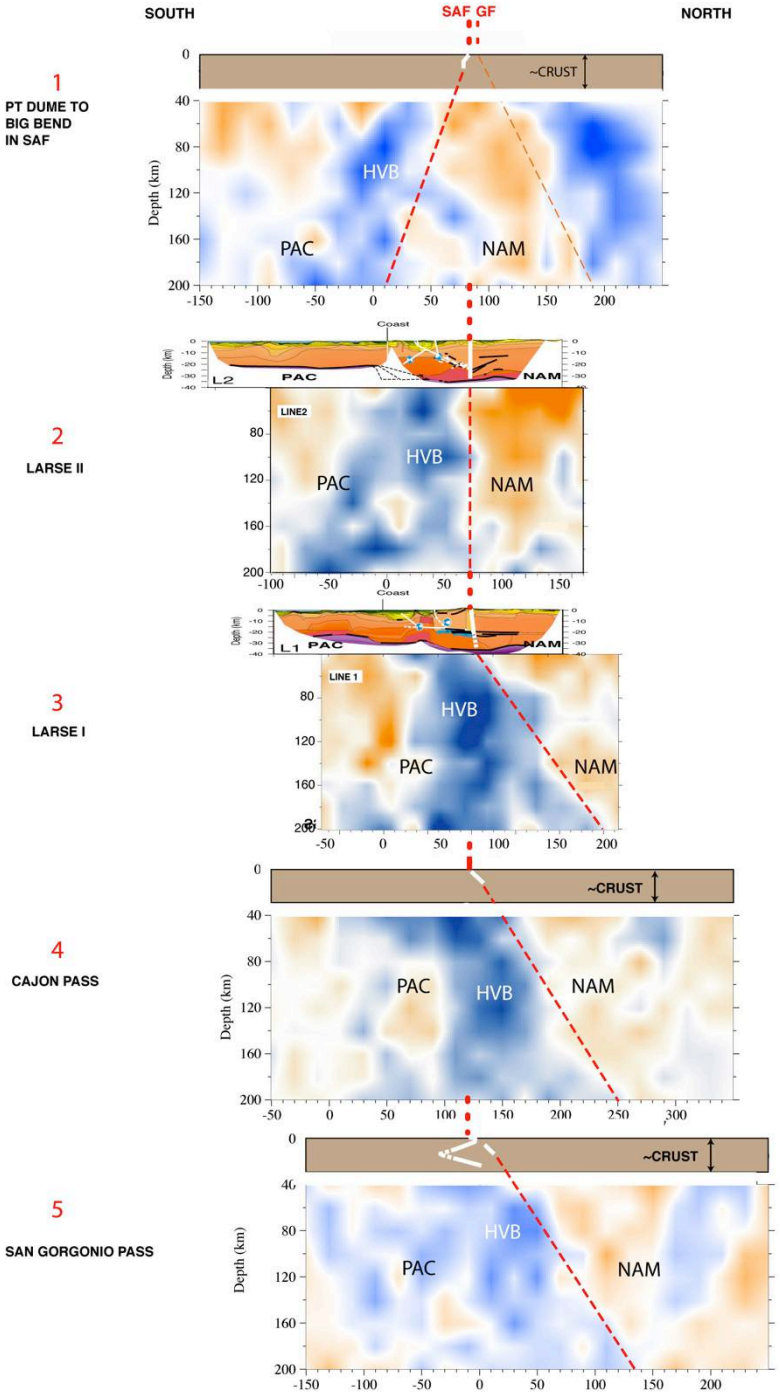

SAN ANDREAS FAULT
Coast
PHT
SMFZ
SGF
Line 1
B
A
DECOLLEMENT
NAM
0
-5
-10
-15
-20
-25
-30
-35
-40
0
50
100
150
Coast
NHF
SGF
Line 2
NF
DECOLLEMENT
NAM
0
-5
-10
-15
-20
-25
-30
-35
-40
0
50
100
150

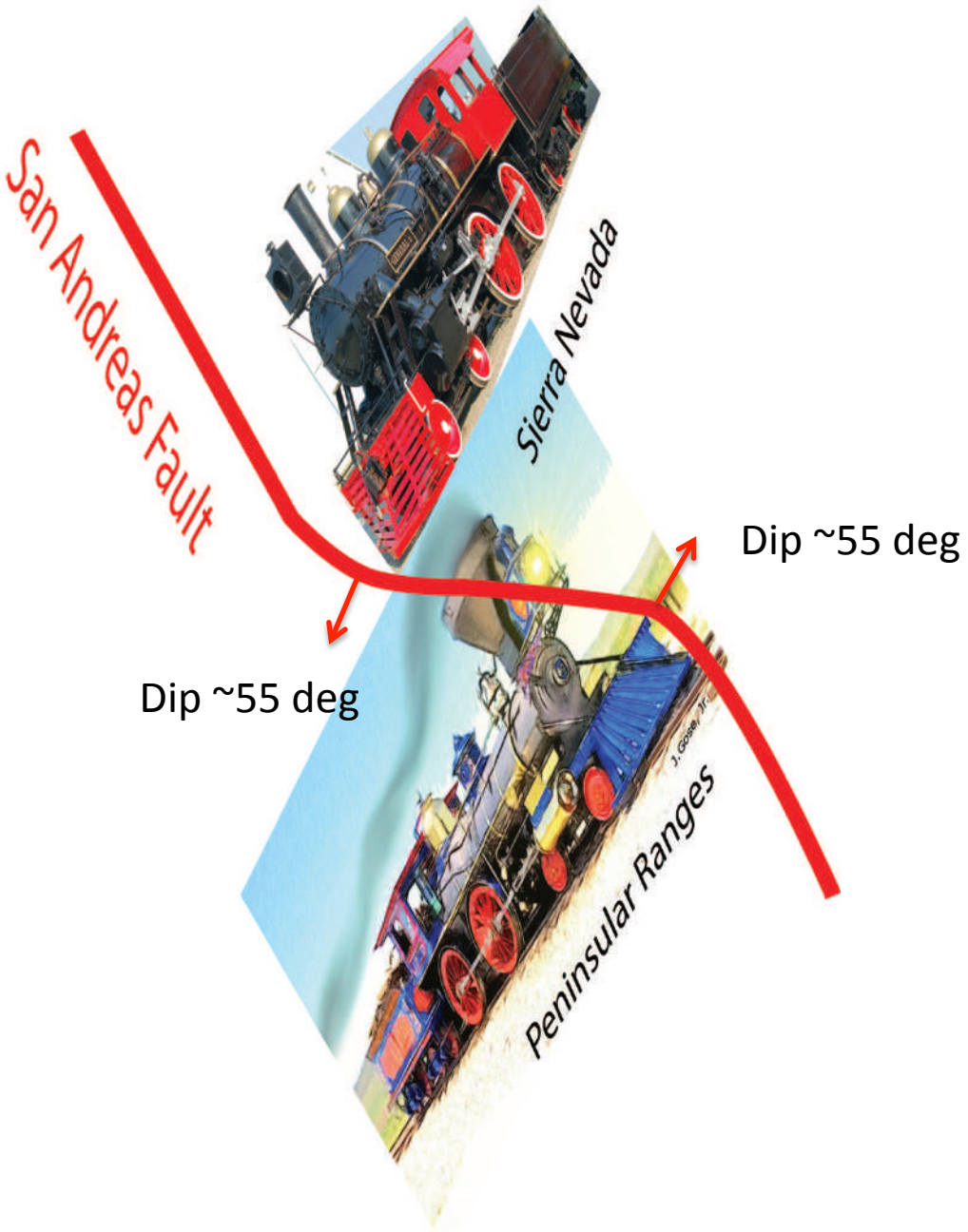


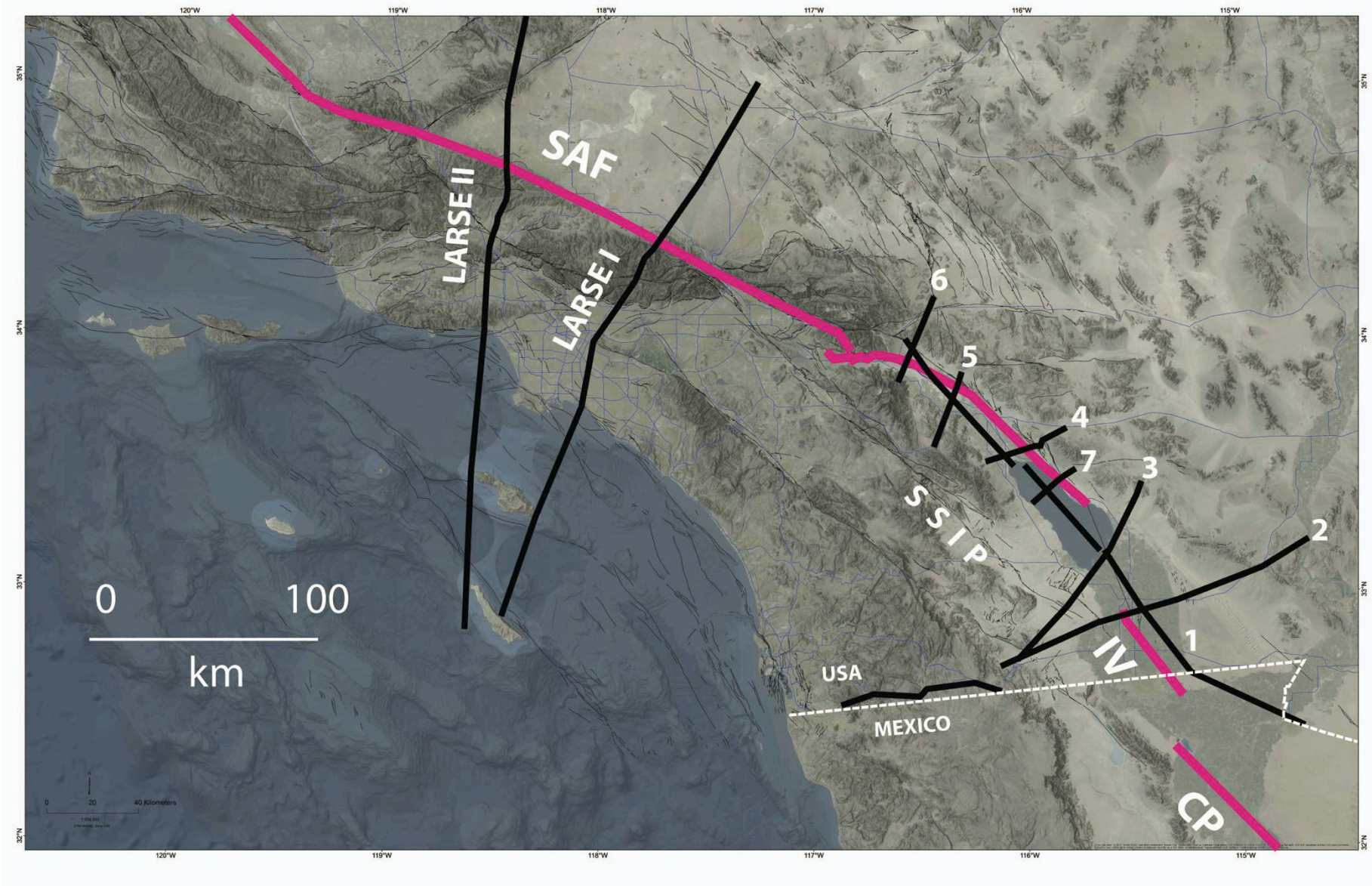
Fuis et al., BSSA, Feb. 2012

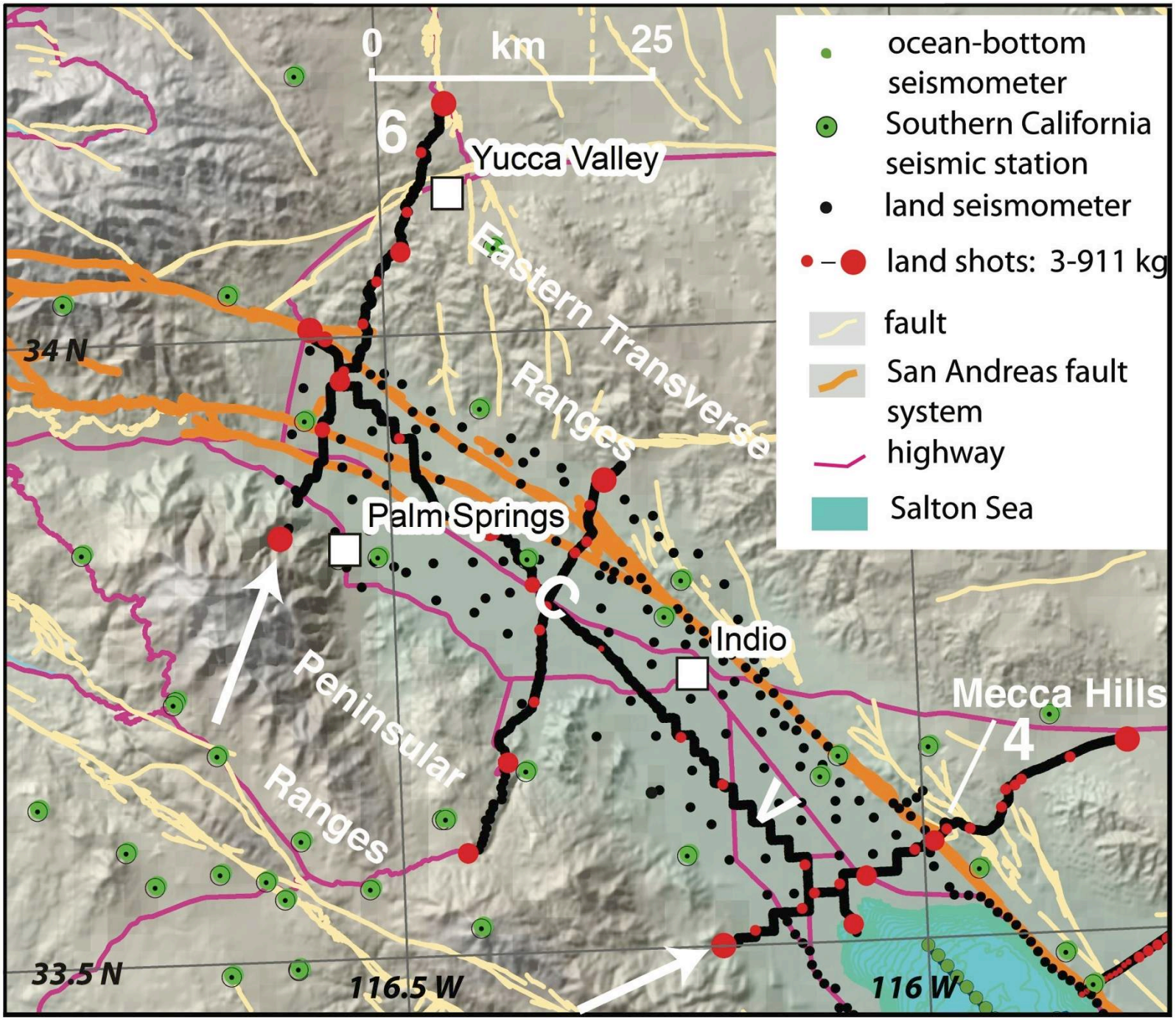
Southern CA EQ Hazard Assessment

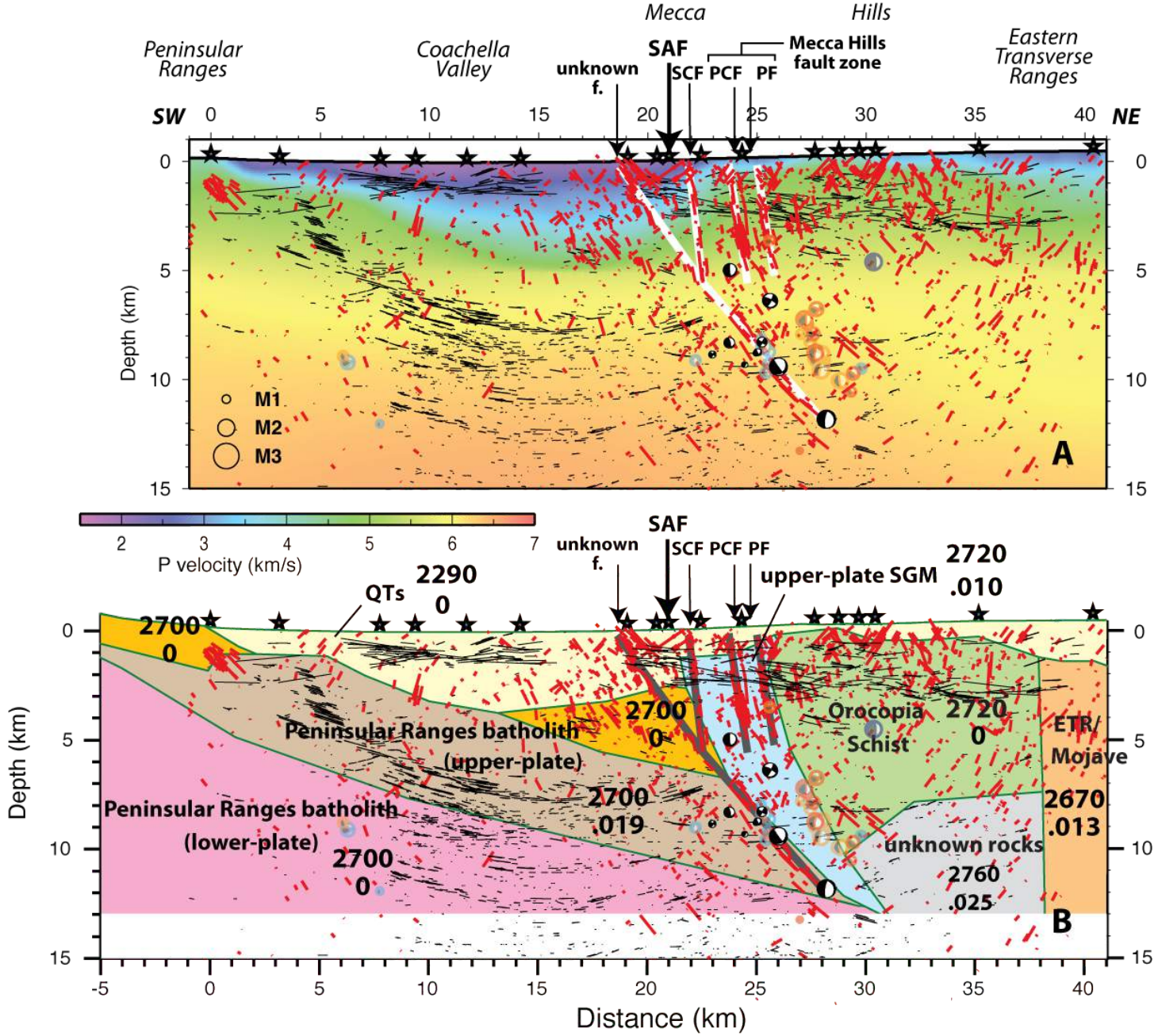

Big Bend
55°
Depth (km)
Distance (km)
S
N
SAN ANDREAS FAULT
Coast
NHF
SGF
SAF
NF
90°
DECOLLEMENT
LARSE II
PHT
SMFZ
85°
LARSE I
0.00 1.40 1.68 2.00 3.00 4.00 5.00 6.00 6.50 6.70 6.80 7.00 7.80 7.90 8.35 8.40 8.60 8.70
VELOCITY (KM/S)
120° W
119° W
118° W
117° W
116° W
36° N
32° N
San Andreas
NORTH AMERICAN PLATE
PACIFIC PLATE
Mojave Desert
Transverse Ranges
Peninsular Ranges
California Continental Borderland
HVB
LAB
(100 km)
50 mm/a
USA
Mexico
0 100 200 km
Rialto-Colton Fault
Loma Linda Fault
San Andreas Fault
Mill Creek Fault
37°
D=2.72 S=0
D=2.25 S=0
D=2.65 S=0
D=2.65 S=0.001
D=2.67 S=0
D=2.65 S=0.002
San Bernardino
V.E.=1:1
GH
B
MC
52°
45°
North Palm Springs
Indio
70°
57°
57°
59°
Creeping section

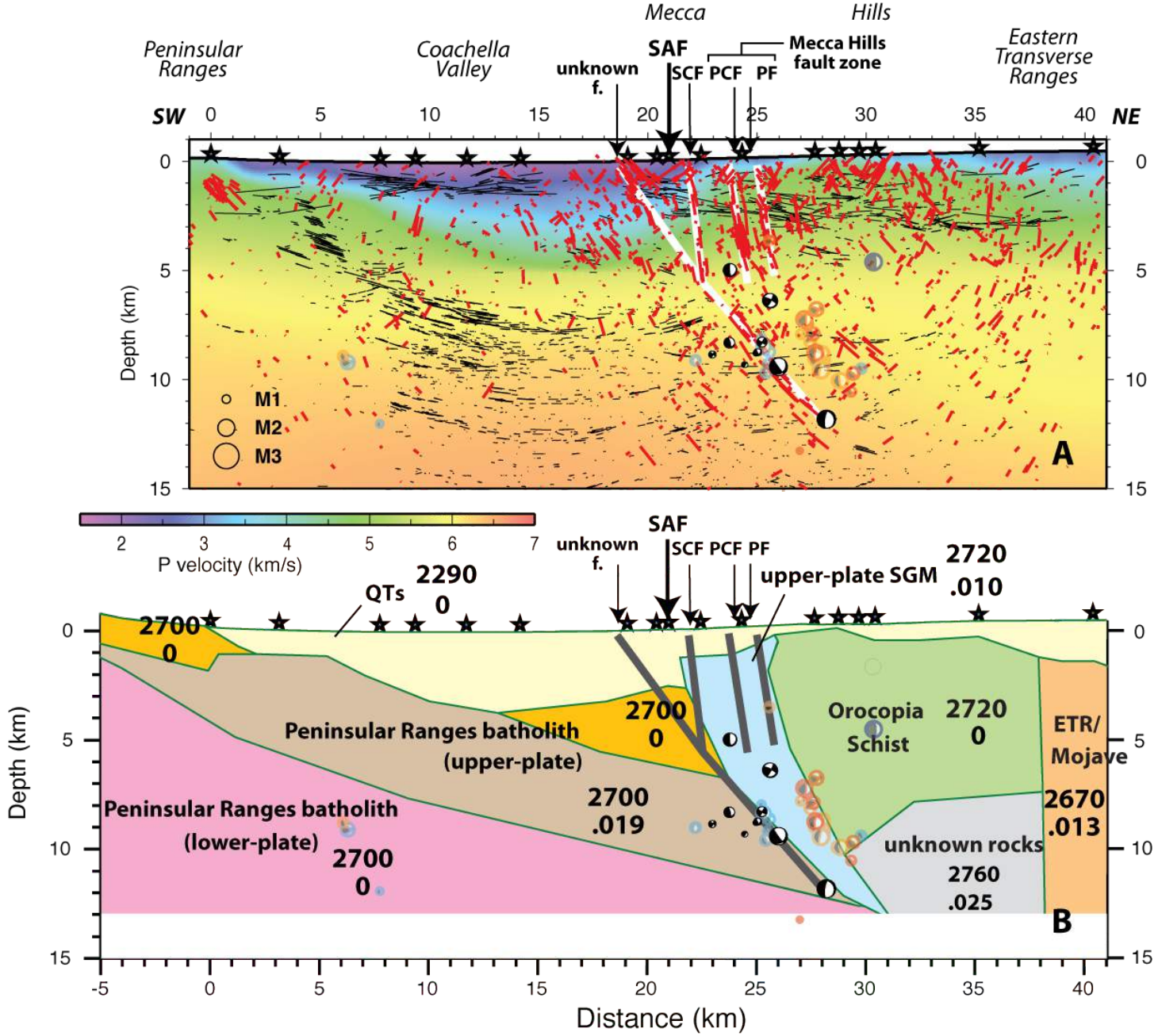

SOUTH
SAF GF
NORTH
1
PT DUME TO
BIG BEND
IN SAF
~CRUST
HVB
PAC
NAM
Depth (km)
Coast
L2
2
LARSE II
LINE2
3
LARSE I
L1
LINE 1
4
CAJON PASS
5
SAN GORGONIO PASS

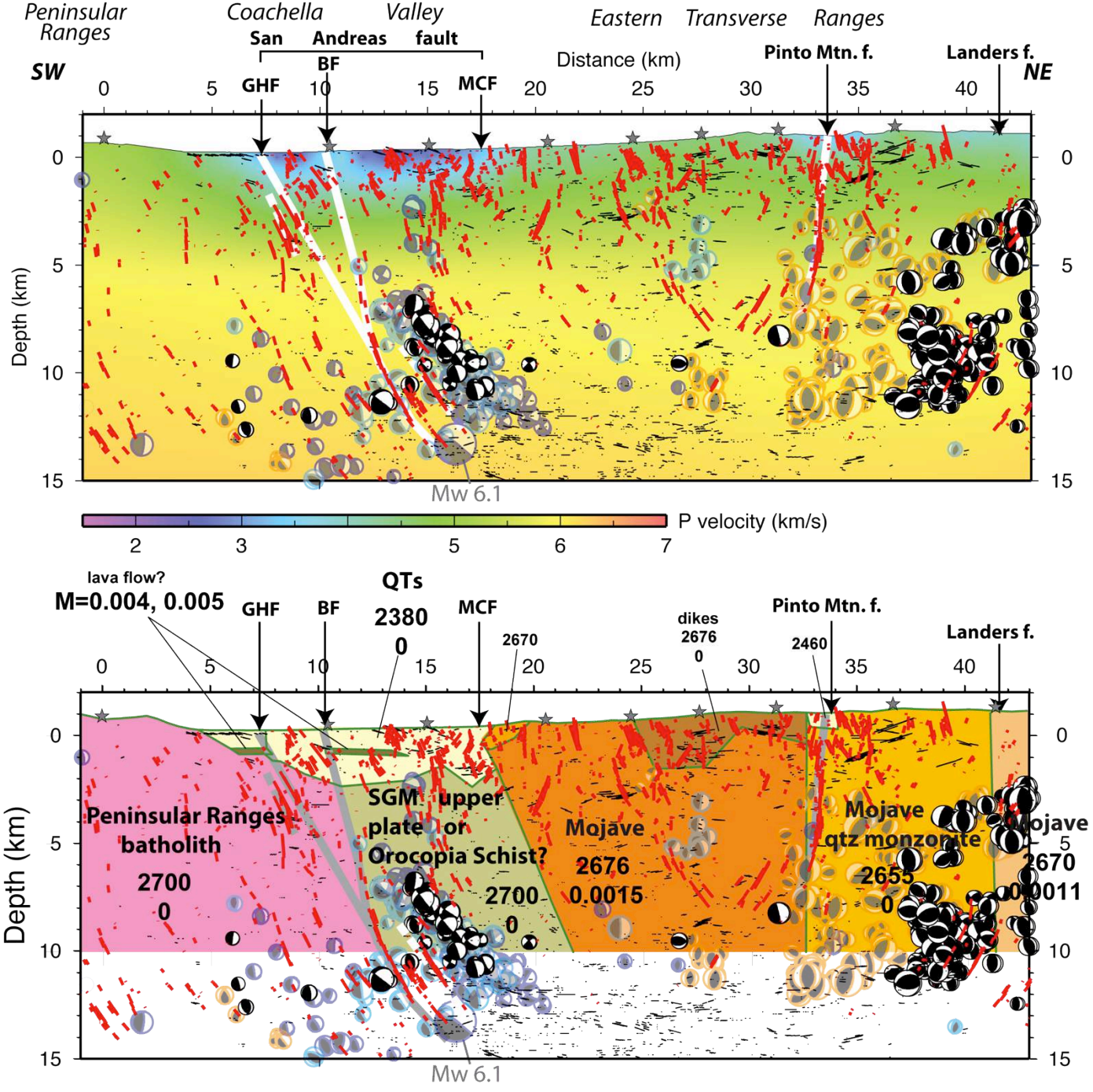

San Andreas Fault
Sierra Nevada
Peninsular Ranges
Dip ~55 deg
Dip ~55 deg

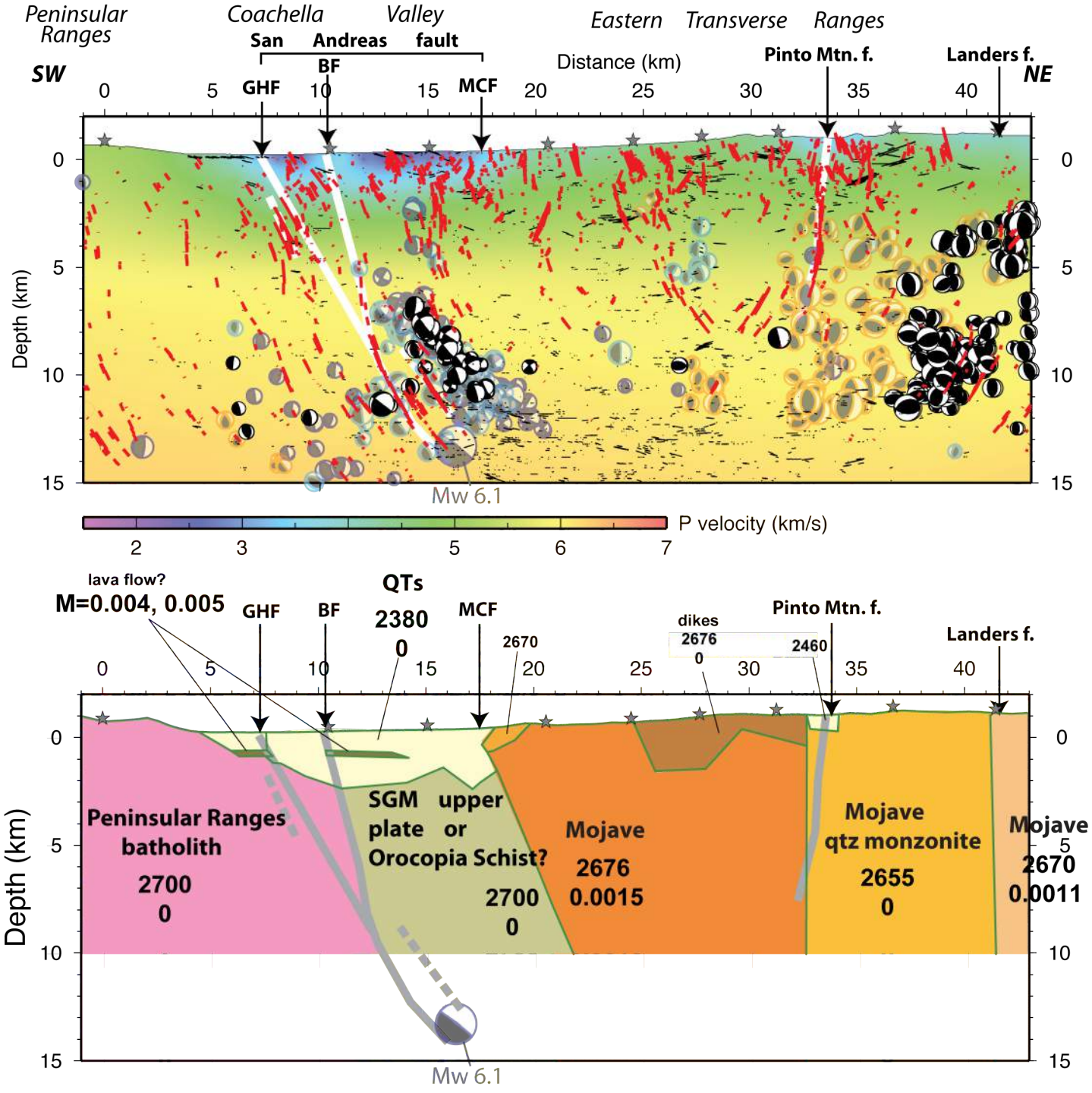

120°W
119°W
118°W
117°W
116°W
115°W
35°N
34°N
33°N
32°N
SAF
LARSE II
LARSE I
6
5
4
7
3
2
1
SSIP
IV
CP
USA
MEXICO
0
100
km
0
20
40 Kilometers


0
km
25
6
Yucca Valley
Eastern Transverse Ranges
34 N
Palm Springs
C
Indio
Peninsular Ranges
V
Mecca Hills
4
33.5 N
116.5 W
116 W
ocean-bottom seismometer
Southern California seismic station
land seismometer
land shots: 3-911 kg
fault
San Andreas fault system
highway
Salton Sea

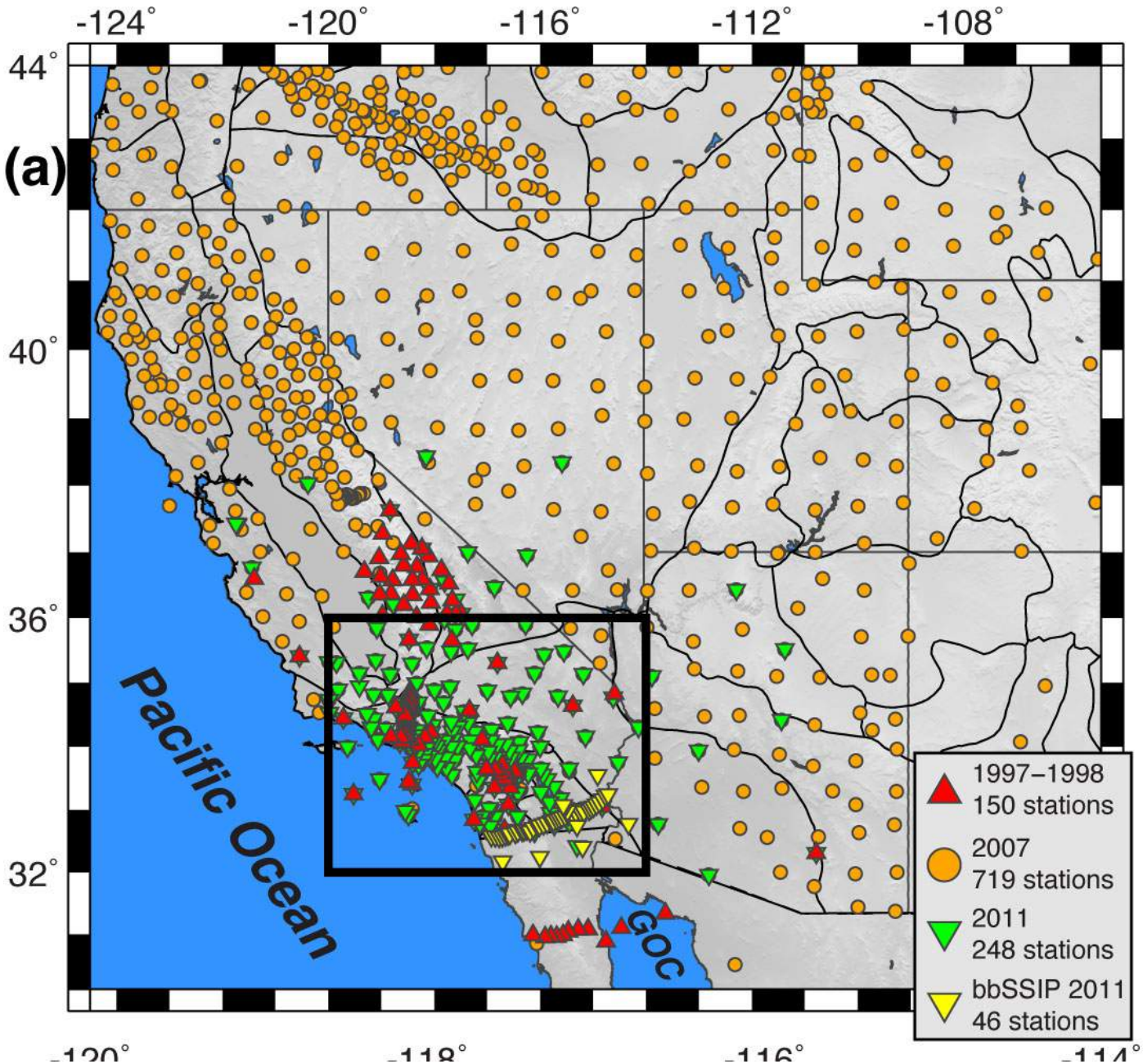

Peninsular Ranges
Coachella Valley
Mecca Hills
Eastern Transverse Ranges
SAF
SCF PCF PF
Mecca Hills fault zone
unknown f.
SW
NE
Depth (km)
M1
M2
M3
A
P velocity (km/s)
QTs
2290
0
2700
0
upper-plate SGM
2720
.010
Peninsular Ranges batholith
(upper-plate)
Peninsular Ranges batholith
(lower-plate)
2700
.019
Orocopia Schist
2720
0
ETR/ Mojave
2670
.013
unknown rocks
2760
.025
B
Distance (km)

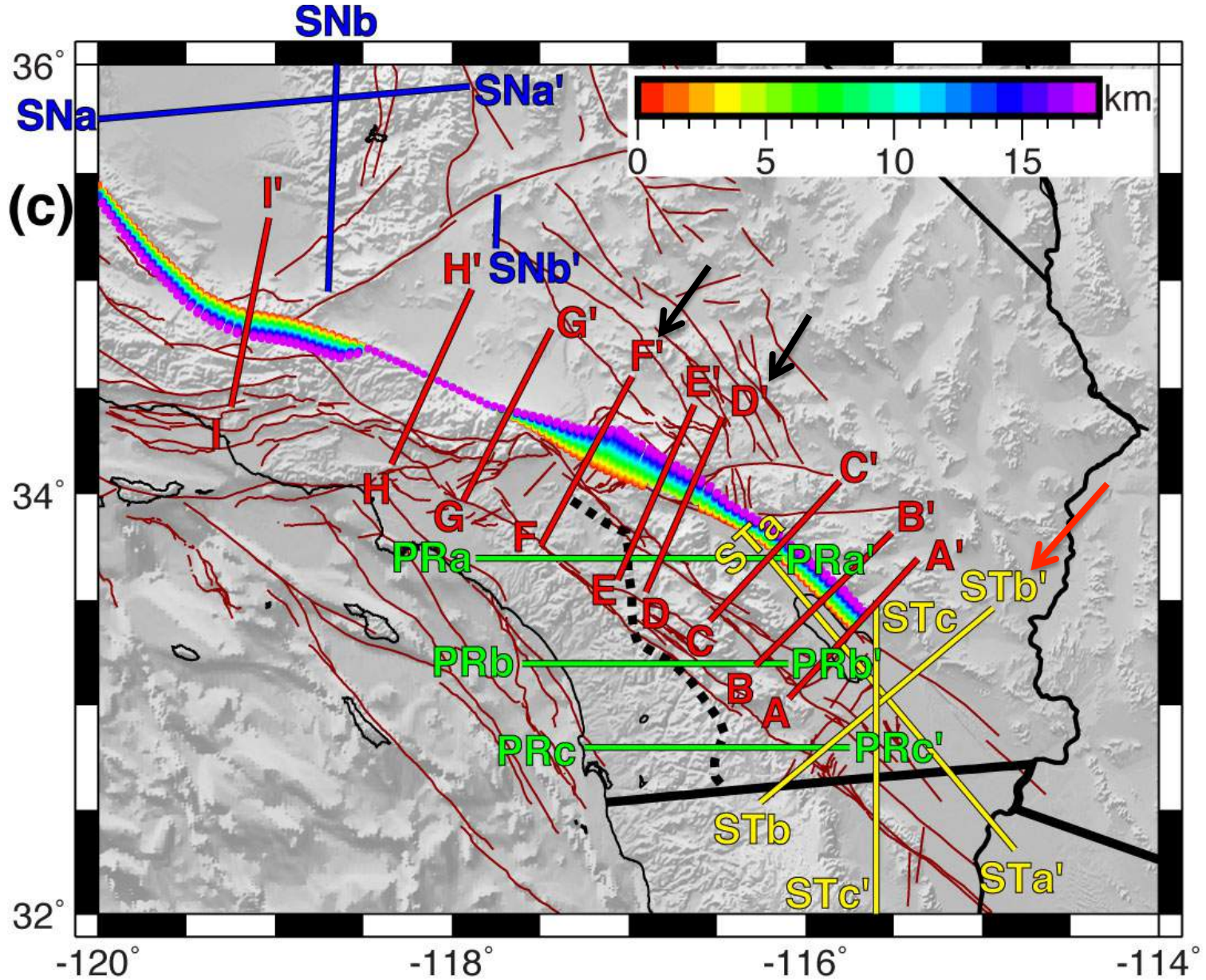

Mecca Hills
Peninsular Ranges
Coachella Valley
SAF
Mecca Hills fault zone
unknown f.
SCF PCF PF
Eastern Transverse Ranges
SW
NE
Depth (km)
M1
M2
M3
A
P velocity (km/s)
QTs
2290
0
2700
0
upper-plate SGM
2720
.010
Peninsular Ranges batholith
(upper-plate)
Peninsular Ranges batholith
(lower-plate)
2700
.019
Orocopia Schist
2720
0
ETR/
Mojave
2670
.013
unknown rocks
2760
.025
B
Distance (km)


Peninsular Ranges
Coachella Valley
San Andreas fault
Eastern Transverse Ranges
SW
NE
GHF
BF
MCF
Pinto Mtn. f.
Landers f.
Distance (km)
Depth (km)
Mw 6.1
P velocity (km/s)
lava flow?
M=0.004, 0.005
QTs
2380
0
2670
dikes
2676
0
2460
Peninsular Ranges batholith
2700
0
SGM upper plate or Orocopia Schist?
2700
0
Mojave
2676
0.0015
Mojave qtz monzonite
2655
0
Mojave
2670
0.0011

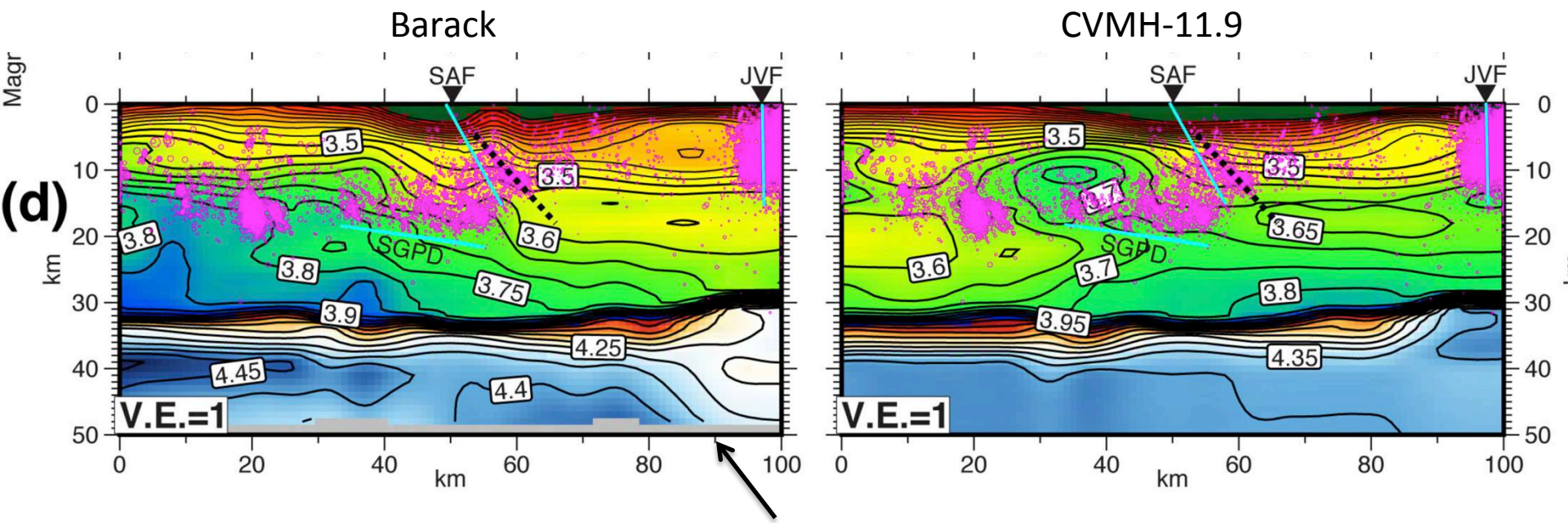

Peninsular Ranges
Coachella Valley
San Andreas fault
Eastern Transverse Ranges
SW
NE
GHF
BF
MCF
Pinto Mtn. f.
Landers f.
Distance (km)
Depth (km)
Mw 6.1
P velocity (km/s)
lava flow?
M=0.004, 0.005
QTs
2380
0
2670
dikes
2676
0
2460
Peninsular Ranges batholith
2700
0
SGM upper plate or Orocopia Schist?
2700
0
Mojave
2676
0.0015
Mojave qtz monzonite
2655
0
Mojave
2670
0.0011

Vs


-124°
-120°
-116°
-112°
-108°
44°
40°
36°
32°
(a)
Pacific Ocean
GOC
1997–1998
150 stations
2007
719 stations
2011
248 stations
bbSSIP 2011
46 stations


SNb
SNa
SNa'
(c)
I'
H'
SNb'
G'
F'
E'
D'
C'
B'
A'
I
H
G
F
E
D
C
B
A
PRa
PRa'
PRb
PRb'
PRc
PRc'
STa
STb
STb'
STc
STc'
STa'
km
0
5
10
15
36°
34°
32°
-120°
-118°
-116°
-114°

Line 6



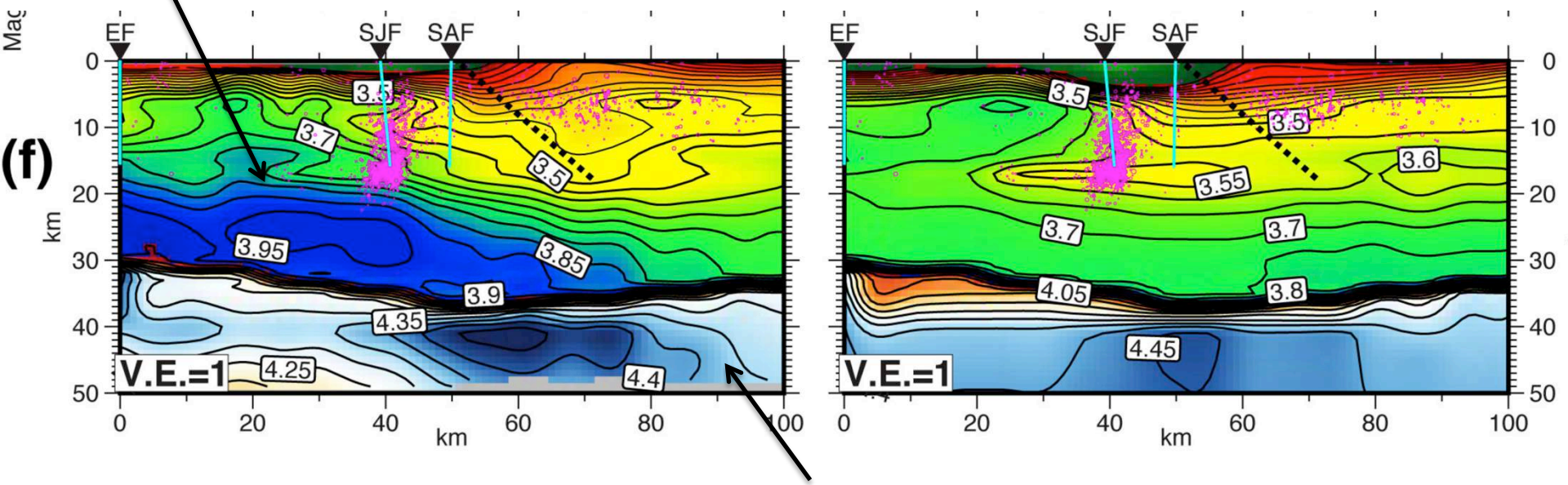
edge mantle high Vs body

lower crust of Peninsular Ranges

San Bernardino

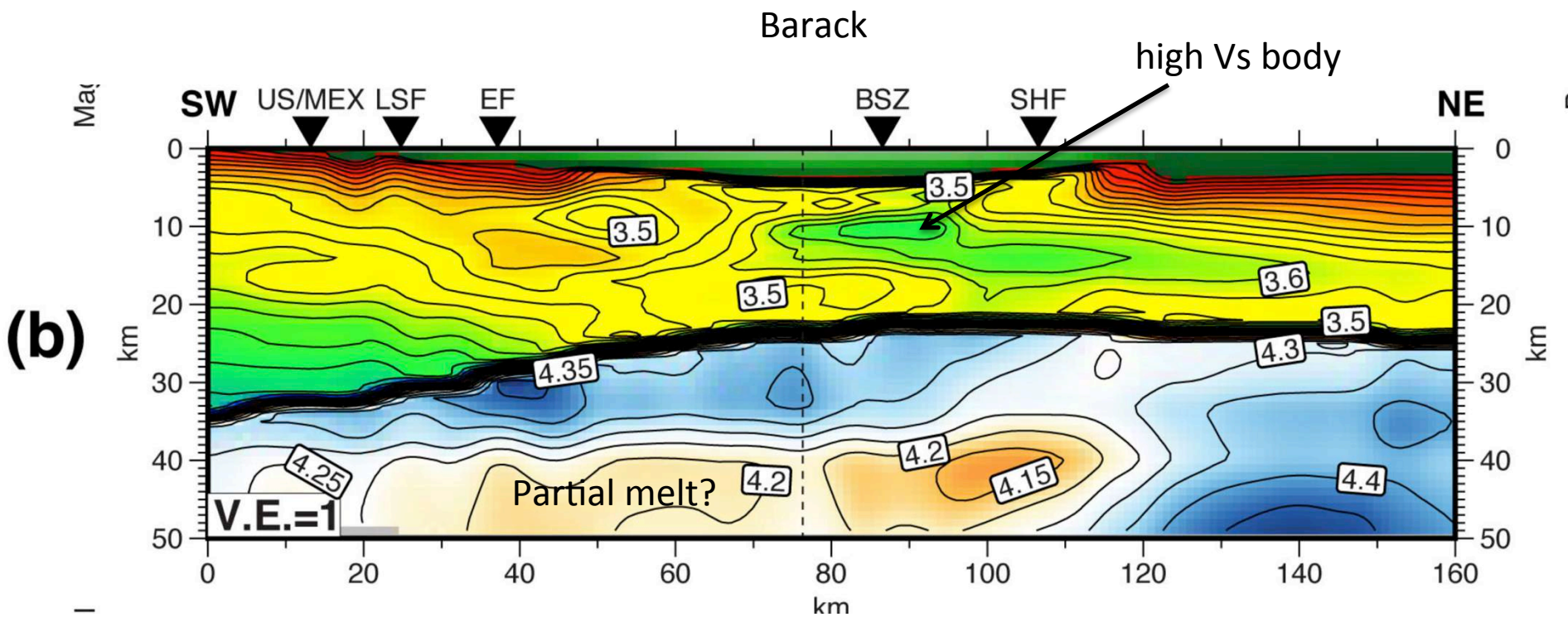
Barack

CVMH-11.9



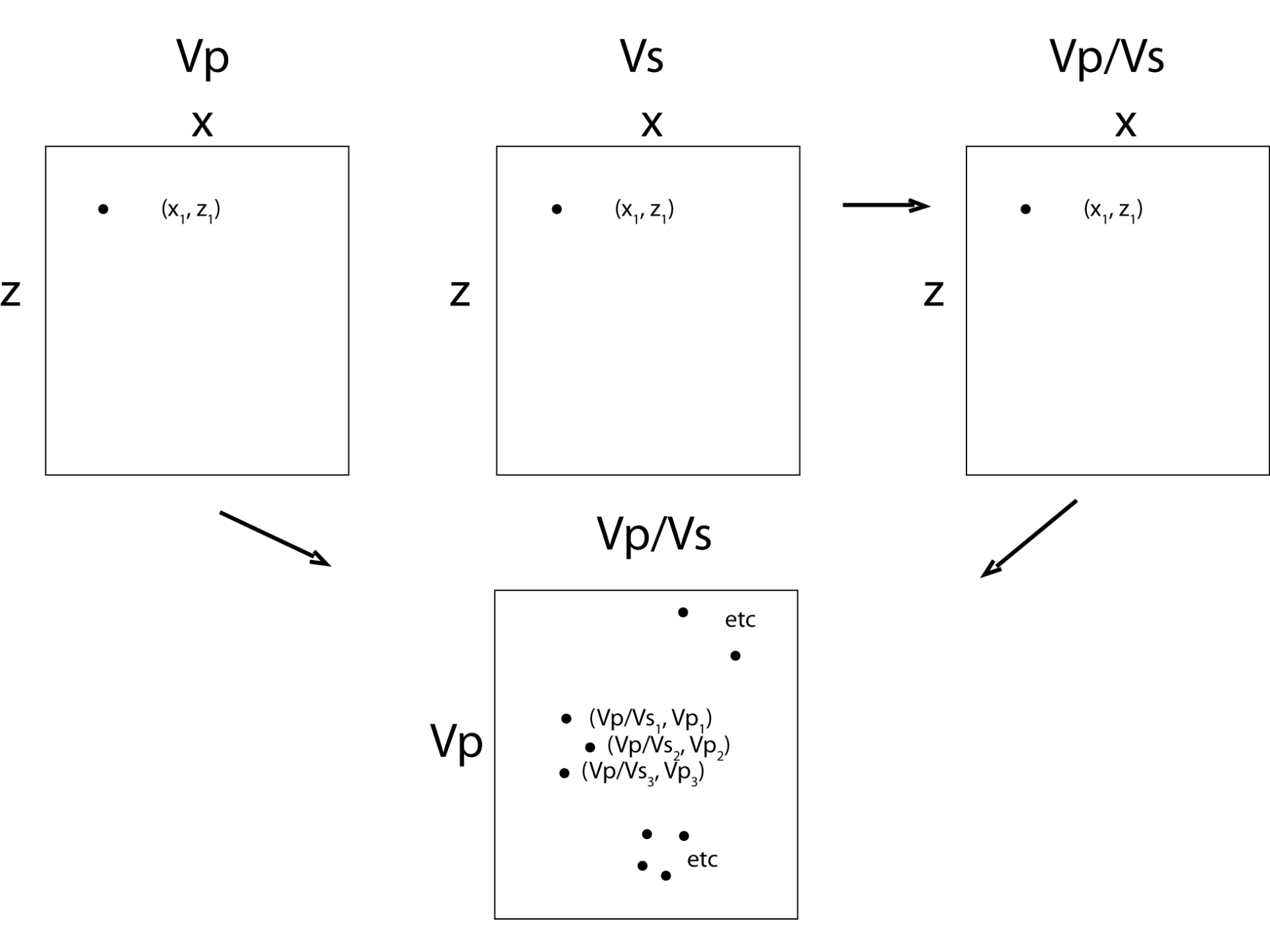
edge mantle high Vs body

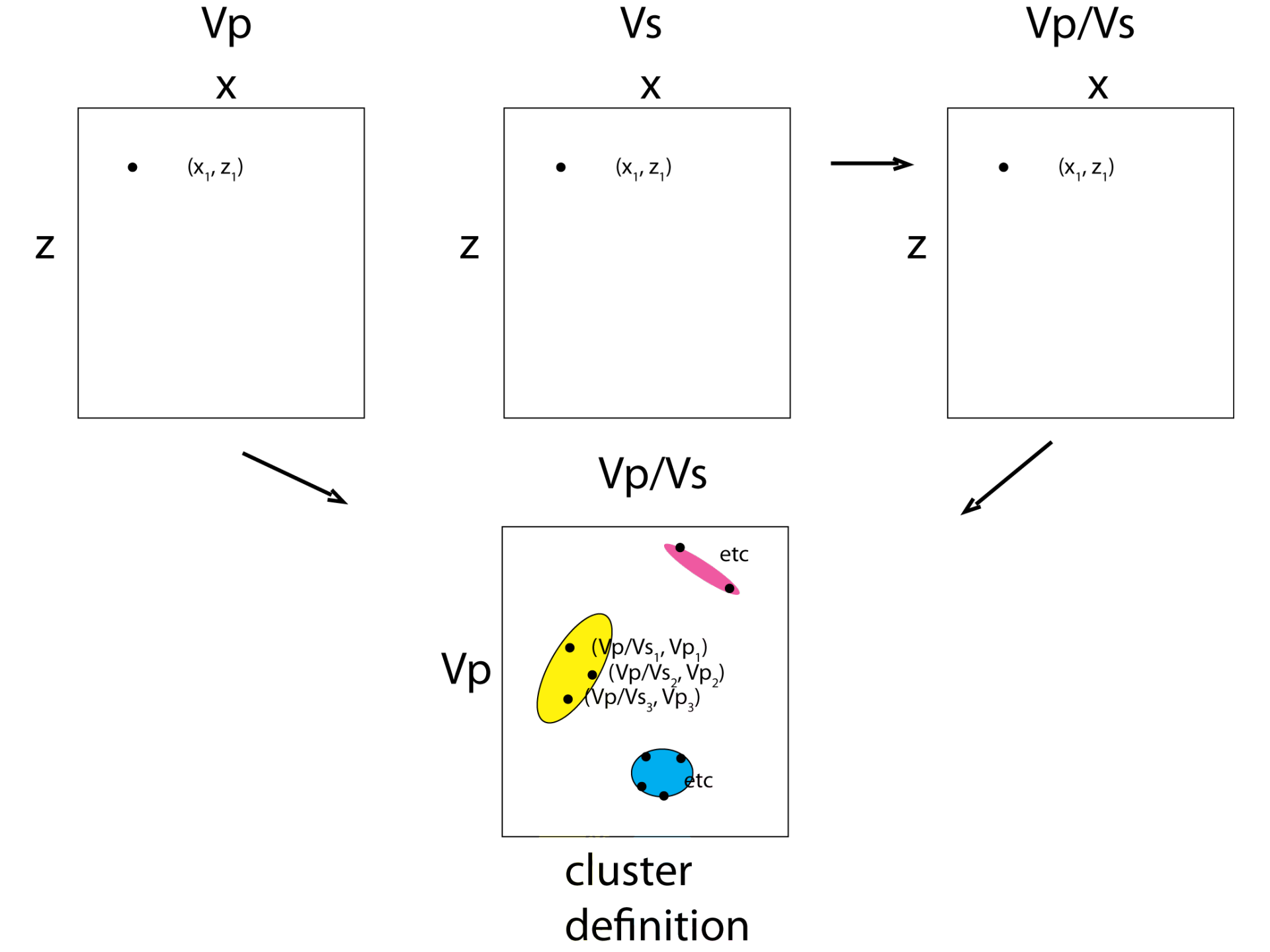
Imperial Valley

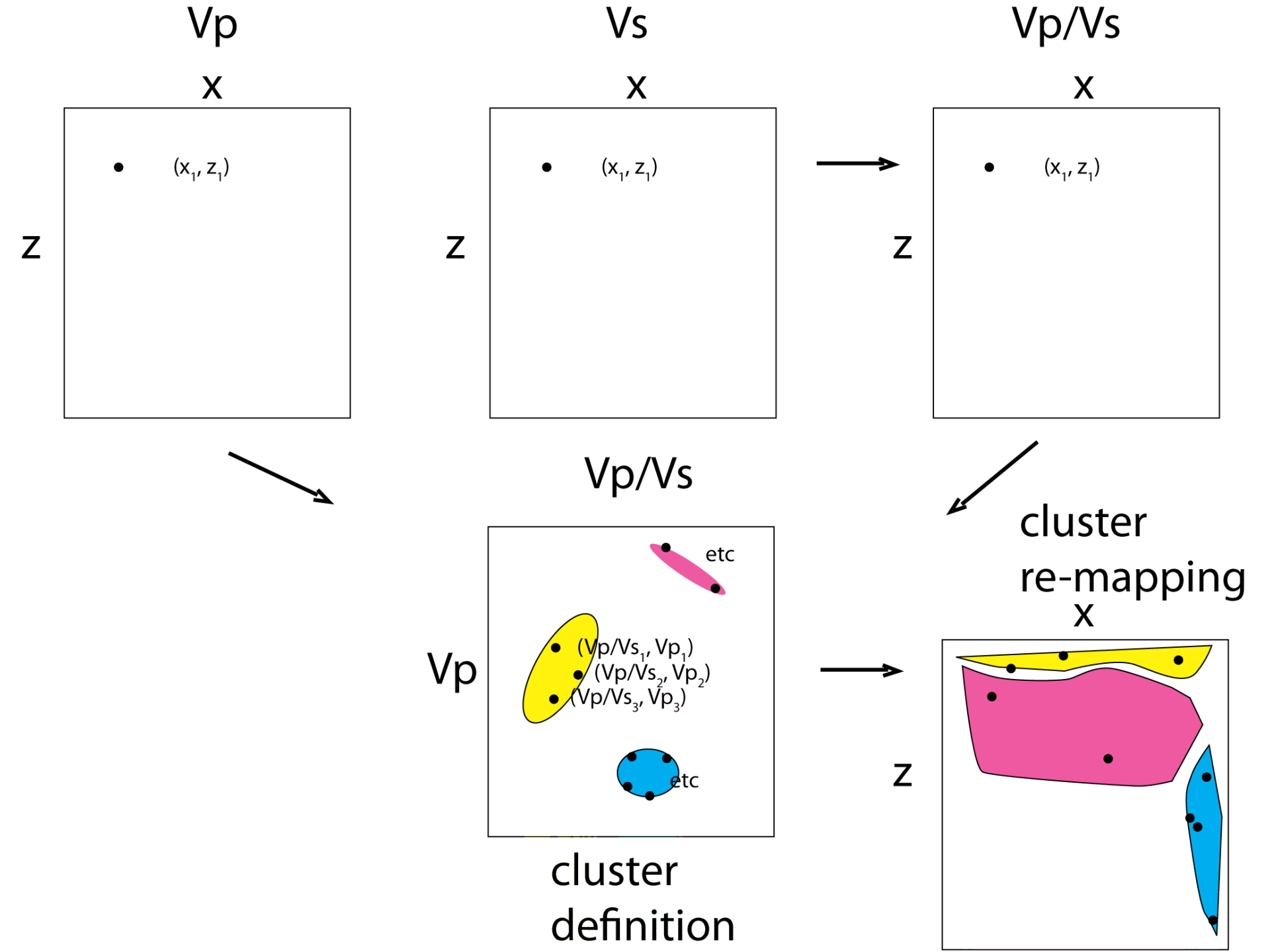


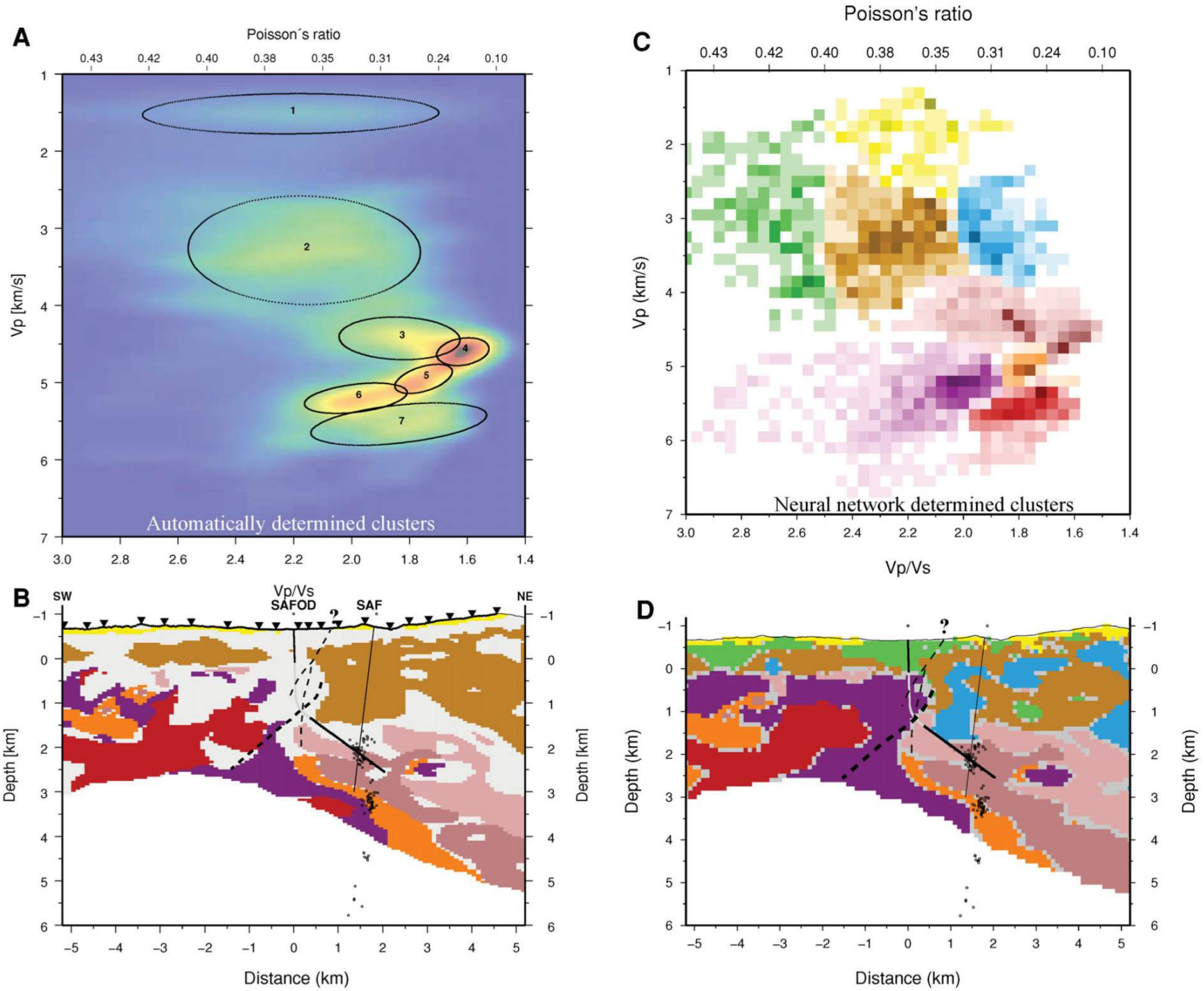

END

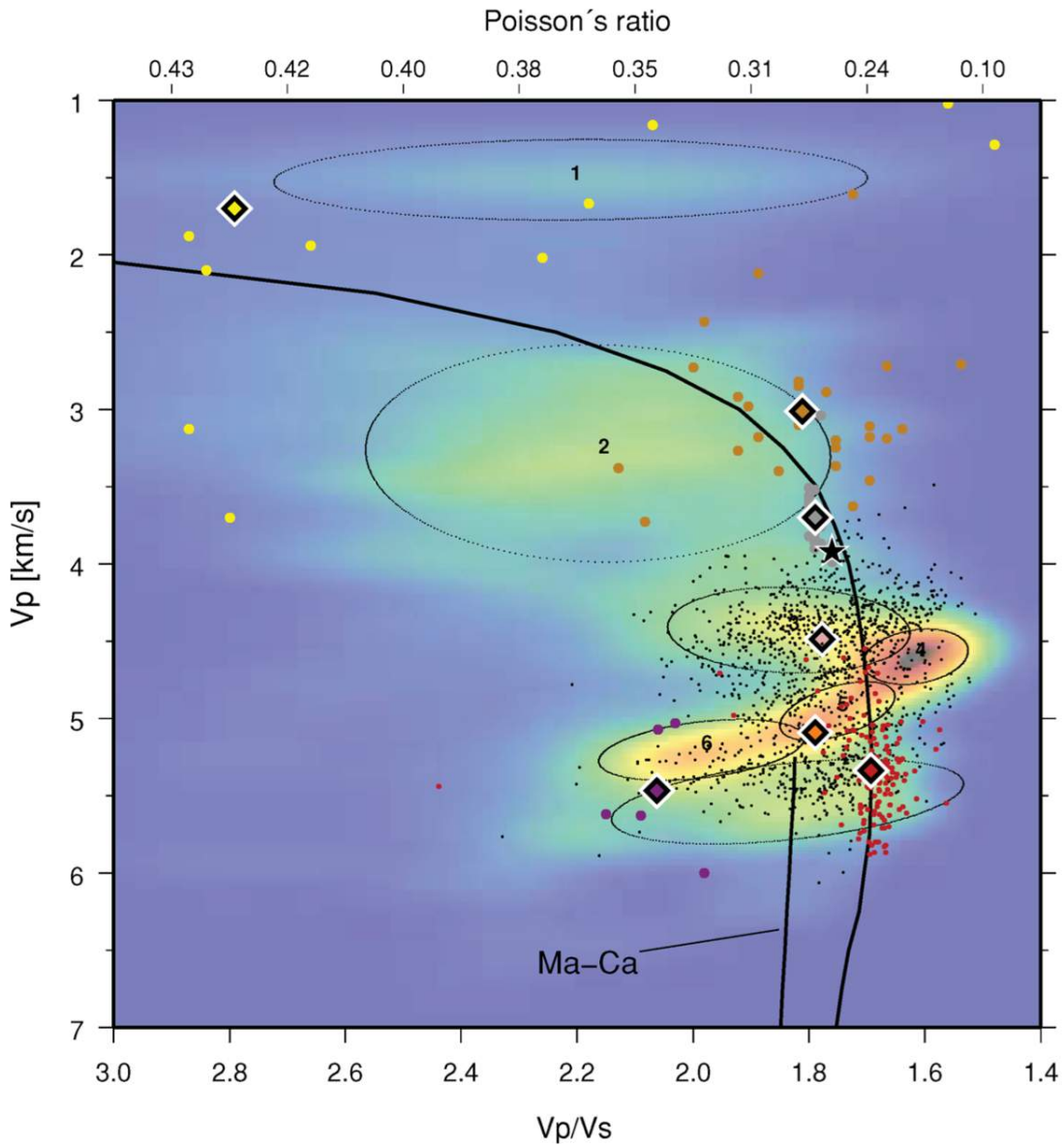
Vp/Vs vs Vp


Vp
x
z
(x_1, z_1)
Vs
x
z
(x_1, z_1)
Vp/Vs
x
z
(x_1, z_1)
Vp/Vs
Vp
etc
$(Vp/Vs_1, Vp_1)$
$(Vp/Vs_2, Vp_2)$
$(Vp/Vs_3, Vp_3)$
etc


Vp
x
z
(x_1, z_1)
Vs
x
z
(x_1, z_1)
Vp/Vs
x
z
(x_1, z_1)
Vp/Vs
Vp
etc
$(Vp/Vs_1, Vp_1)$
$(Vp/Vs_2, Vp_2)$
$(Vp/Vs_3, Vp_3)$
etc
cluster
definition


Vp
x
z
(x_1, z_1)
Vs
x
z
(x_1, z_1)
Vp/Vs
x
z
(x_1, z_1)
Vp/Vs
Vp
etc
$(Vp/Vs_1, Vp_1)$
$(Vp/Vs_2, Vp_2)$
$(Vp/Vs_3, Vp_3)$
etc
cluster definition
cluster re-mapping
x
z


A
Poisson´s ratio
0.43 0.42 0.40 0.38 0.35 0.31 0.24 0.10
Vp [km/s]
1 2 3 4 5 6 7
3.0 2.8 2.6 2.4 2.2 2.0 1.8 1.6 1.4
Automatically determined clusters
C
Poisson's ratio
0.43 0.42 0.40 0.38 0.35 0.31 0.24 0.10
Vp (km/s)
Neural network determined clusters
Vp/Vs
B
SW
Vp/Vs
SAFOD
SAF
NE
Depth [km]
Distance (km)
D
Depth (km)
Distance (km)



DATA POINTS

- [Weathered rocks: Tertiary seds, Franciscan rocks (<30m)]
- Miocene seds, Varian well
- [Franciscan graywacke (Geysers, CA well)]
- ★ SAFOD damage–zone rocks, average (minor volume)
- SAFOD Great Valley sequence seds.
- SAFOD arkoses (chiefly Paleocene)
- [Serpentinite]
- SAFOD granitic rocks

Brackets enclose non–local rock types

END2