GLG494/598 (ASU) and GEOL 701J (UNR): Mapping tectonic faults from geomorphology

Refining fault zone mapping approaches and examples

Ramón Arrowsmith

ramon.arrowsmith@asu.edu

School of Earth and Space Exploration

Arizona State University

Outline for today’s lecture

- Review example of California Geological Survey Fault Evaluation Report results
- Reminder of the main motivations of the course and activity
- Heuristics by demonstration: examples of fault maps
- Workflows and database schema examples

California Geological Survey
Fault Evaluation Report FER-264

THE RAYMOND FAULT
in the Mt. Wilson and El Monte Quadrangles
Los Angeles County, California

by
Jerome A. Treiman
April 20, 2017 (revised)

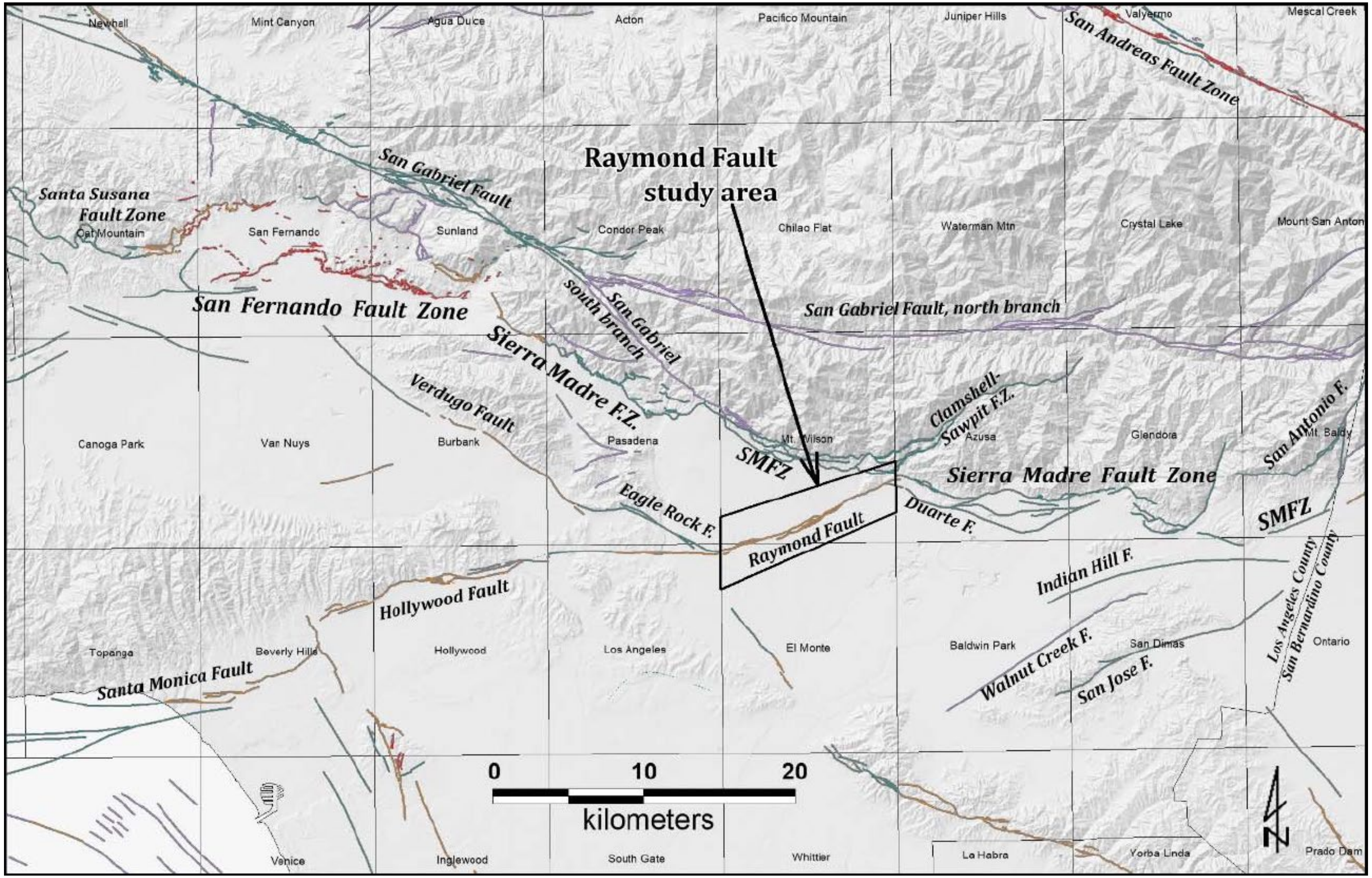
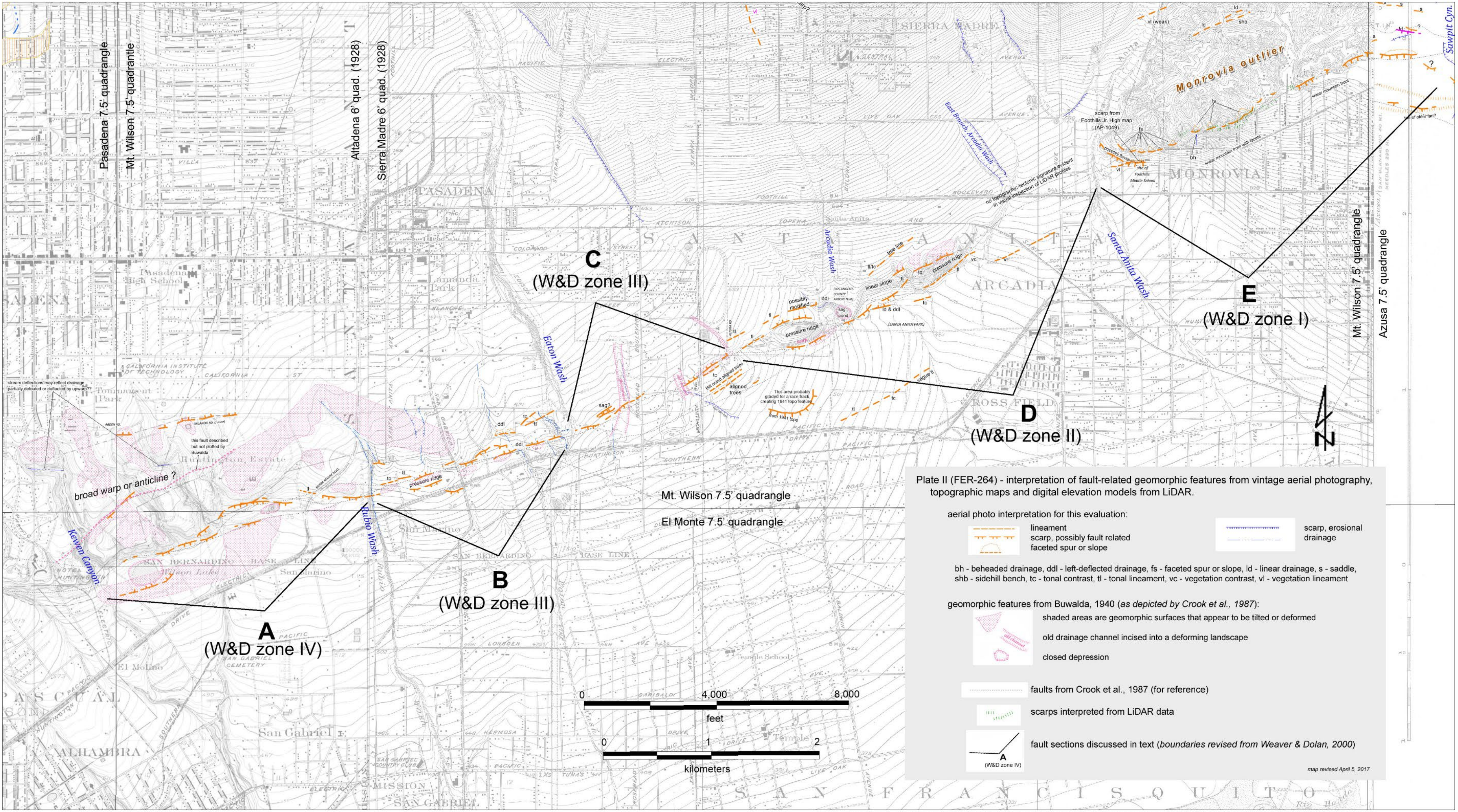
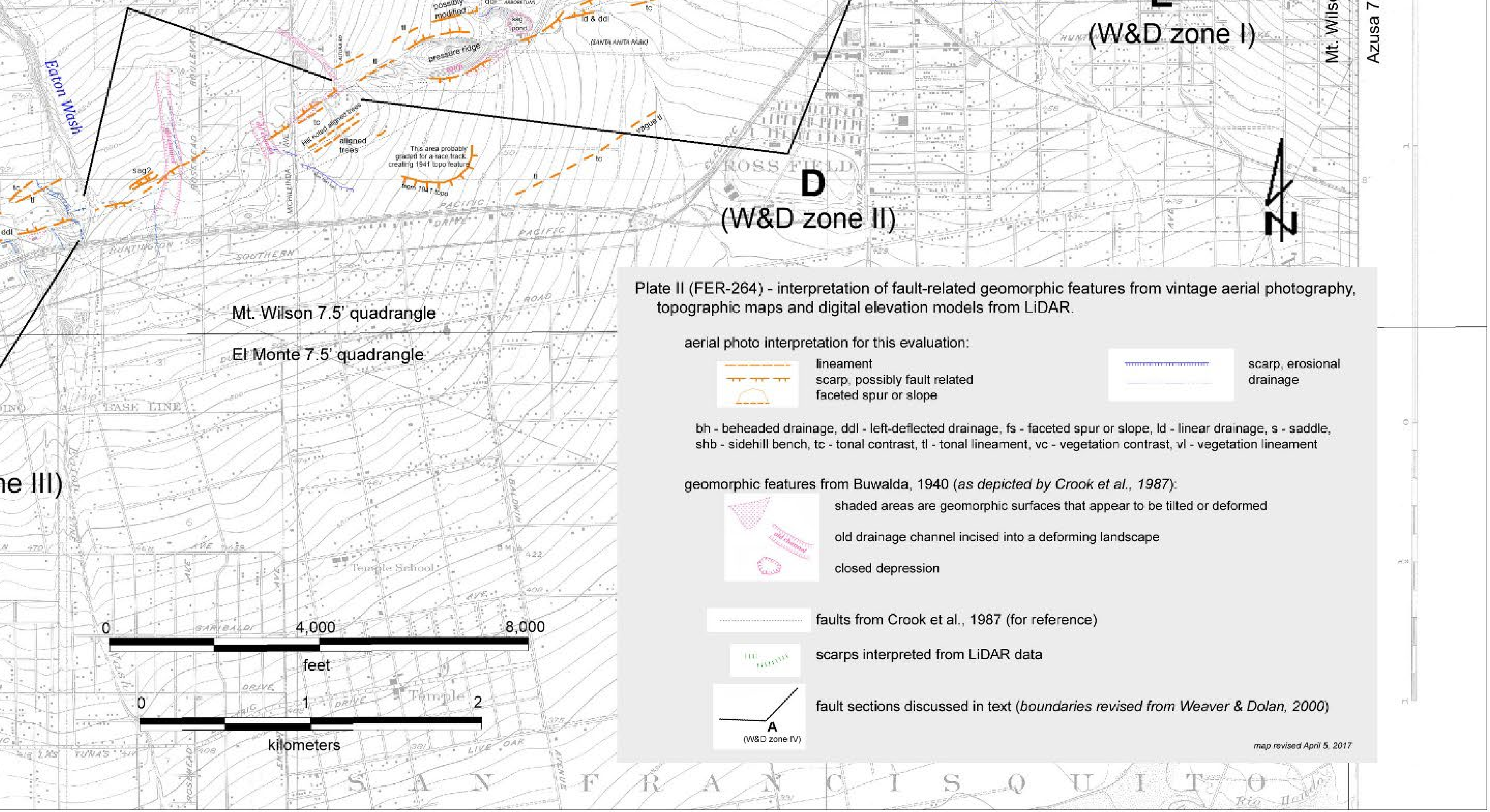


Plate 2 is useful for the class – A tectonic geomorphic map that Jerry produced, mostly from older airphotos (although the topo base shows many of the features pretty well). I think Plate 3 helps illustrate the evolution of many pieces of data into a unified fault map.

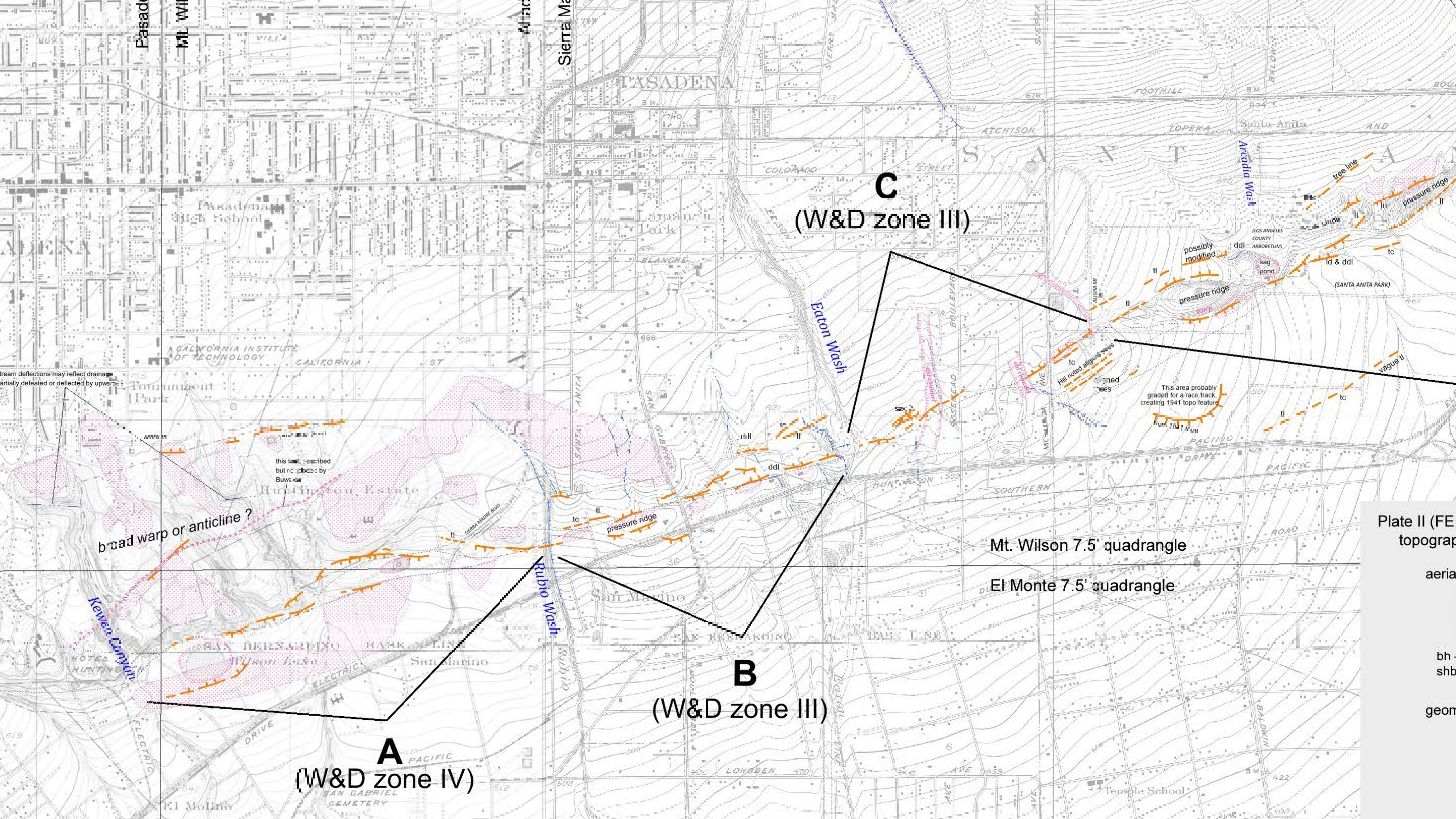
-Dawson



base map is a composite of portions of the Altadena and Sierra Madre 6-minute quadrangles, published in 1928 at a scale of 1:24,000



base map is a composite of portions of the Altadena and Sierra Madre 6-minute quadrangles, published in 1928 at a scale of 1:24,000



C
(W&D zone III)
B
(W&D zone III)
A
(W&D zone IV)
Mt. Wilson 7.5' quadrangle
El Monte 7.5' quadrangle
Plate II (FE
topograp
aeria
bh -
shb
geom
broad warp or anticline ?
this fault described
but not plotted by
Buwalda
pressure ridge
This area probably
graded for a race track
creating 1941 topo feature
from 1941 topo
aligned
trees
sag?
linear slope
tree line
vague tl
possibly
modified
Kewen Canyon
Rubio Wash
Eaton Wash
Arcadia Wash
PASADENA
Pasadena
High School
CALIFORNIA INSTITUTE
OF TECHNOLOGY
Tournament
Park
Huntington Estate
Lamanda
Park
San Marino
Wilson Lake
SAN BERNARDINO BASE LINE
El Molino
SAN GABRIEL
CEMETERY
Temple School
HOTEL
HUNTINGTON
(SANTA ANITA PARK)
COLORADO
FOOTHILL
ATCHISON
TOPEKA
CALIFORNIA
ST
PACIFIC
DRIVE
SOUTHERN
HUNTINGTON
ELECTRIC
LONGDEN

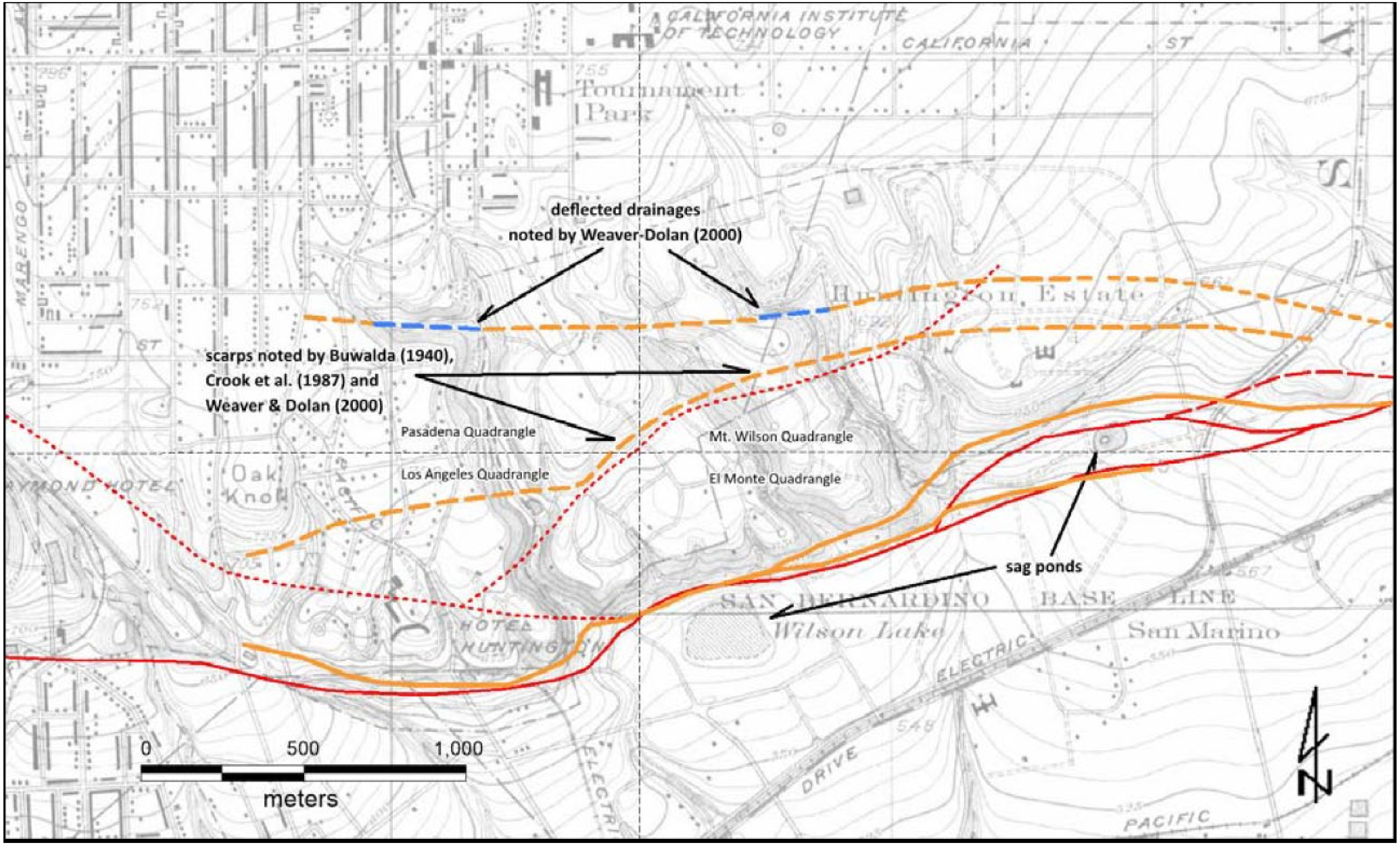


Figure 8 – Detail of San Marino area, showing interpreted features from Buwalda (1940), Crook *et al.* (1987; red lines) and Weaver and Dolan (2000; orange lines). The two later interpretations were very close to that of Buwalda, for the main fault trace. Base map is part of 1928 Altadena 6' quadrangle map.

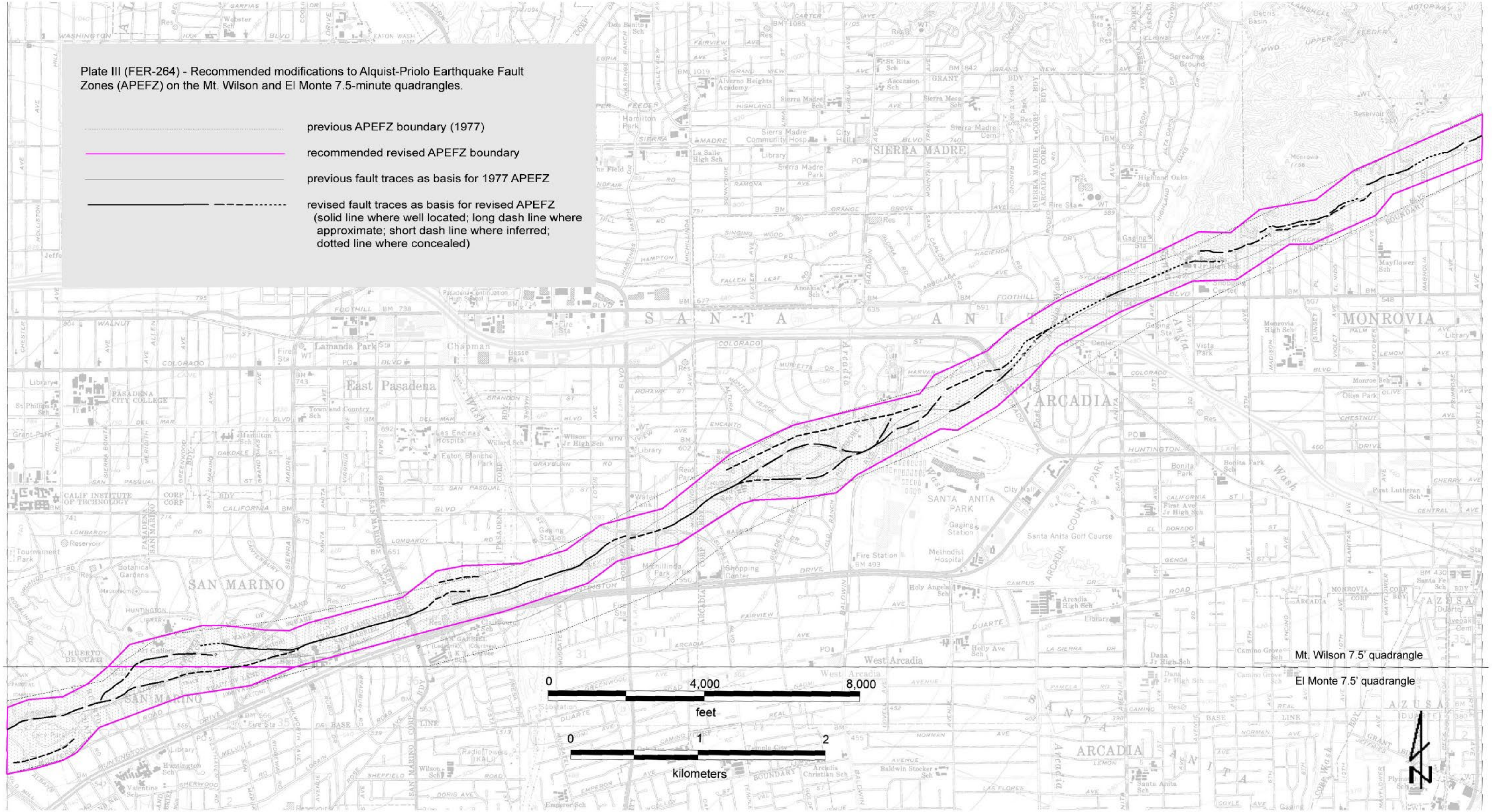


Plate III (FER-264) - Recommended modifications to Alquist-Priolo Earthquake Fault Zones (APEFZ) on the Mt. Wilson and El Monte 7.5-minute quadrangles.

What is the fault rupture hazard at sites near active faults?

First step is what we are doing in our class which is to MAP fault traces and deformation zones active in the recent geologic past.

We are helping you fill your toolbox: morphologic mapping, surficial geologic mapping, geomorphic indicator ranking, fundamental structural geology and geomorphology, Quaternary climate drivers, QGIS, etc.

From the standpoint of improving PFDHA models for hazard, it will be most helpful to have the pre-rupture maps reflect the *current standard of practice* for mapping fault location, location uncertainty, etc. This standard of practice does pay attention to reasonable geologic constraints and follows well-traveled heuristics [“rules-of-thumb”] about which features are good proxies for active faulting versus differential erosion/not active faulting.

The comparison of pre- and post-rupture mapping should be the objective test for us all to learn how well the fault mapping—following current best practices—serves as a predictive tool for future surface-fault rupture. We want to use this comparison to develop additional data for calibration of the PFDHA models, as well as assess the best approaches for producing useful map data.

-S. Thompson

The challenge for us then is to balance moving our mapping closer to the standards of practice without also introducing too much additional bias, or too much reliance on prior knowledge. [somewhat generic educational challenge for many situations]

We have a great opportunity with our motivated group of geoscientists to address these issues

Mapping Strategies, Guidance, Considerations

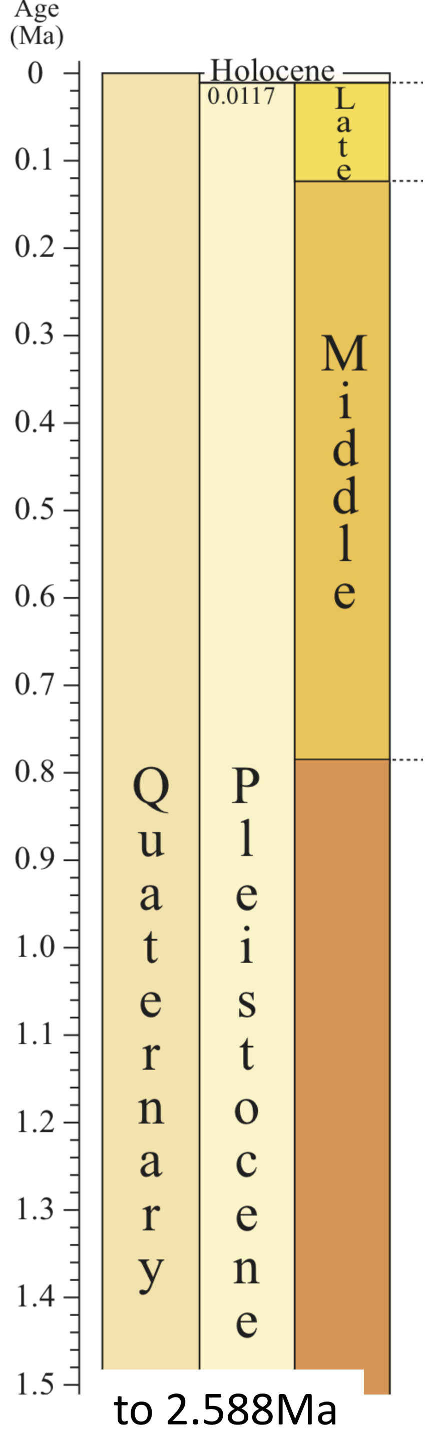
- Generic geologic, geomorphic, morphologic mapping standards
- California Geological Survey active fault guidelines
- McCalpin flow chart
- Controls by slip rate, fault type, vegetation and anthropogenic changes, active and paleosurface processes
- Many examples (heuristics by demonstration)

Quality rating for our maps

- Basic rules
  - Bedrock and Quaternary geology correctness
  - Missing features & Uneven coverage
  - Consistency
- How to document your decision making? Is the feature related to active faulting
- Are the features you have drawn supported by the observations?

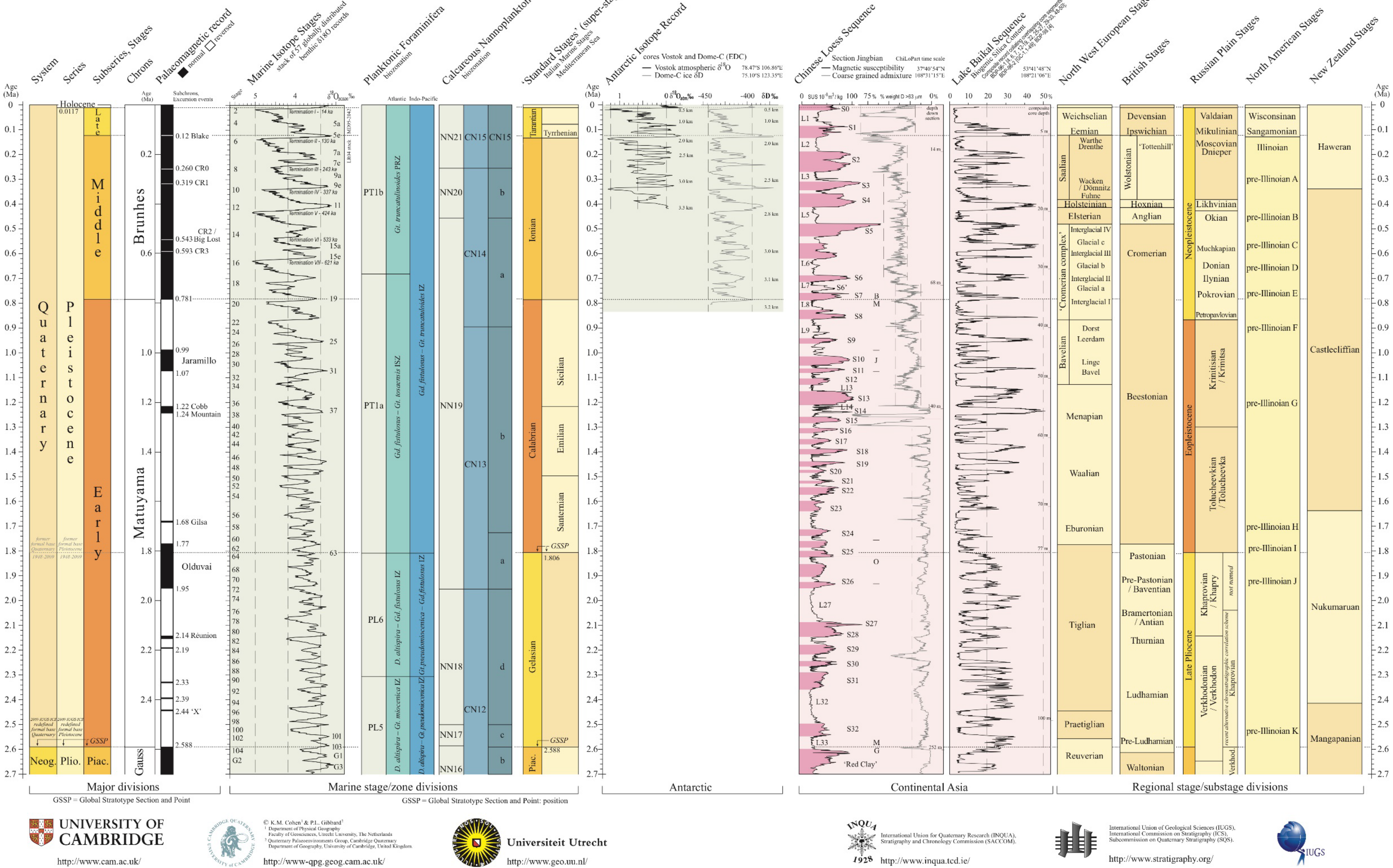
Active faults—defined by recency of last ground deformation

- USGS Quaternary faults 5 classes: Historic, Holocene to Latest Pleistocene, Late Quaternary, Mid-Late Quaternary, Quaternary (https://www.usgs.gov/natural-hazards/earthquake-hazards/faults)
- California Geological Survey maps: Holocene (<12ka)
- California Division of Dams: Late Pleistocene (<35ka)
- Holocene is post Last Glacial Maximum



Global chronostratigraphical correlation table for the last 2.7 million years

v. 2011



http://quaternary.stratigraphy.org/charts/

Heuristics by demonstration: examples of fault maps
Let’s see how other groups have solved these problems
This is not exhaustive

Let’s look for

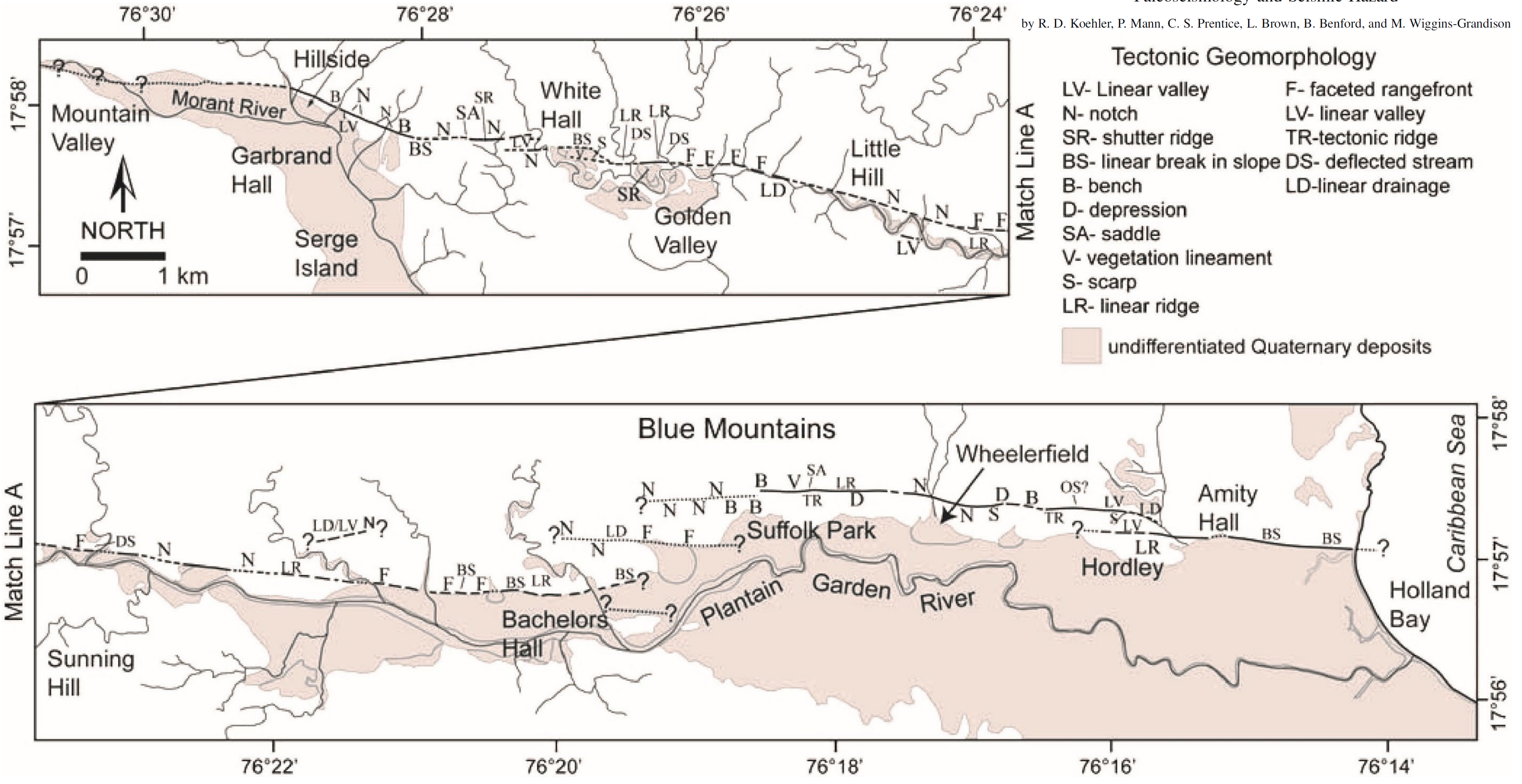
- Morphologic features
- GIR
- Surficial Geologic mapping
- Primary vs. secondary
- How well are the mapped features supported by the data?

Heuristics by demonstration: examples of fault maps: Enriquillo-Plaintain Garden Fault, Jamaica

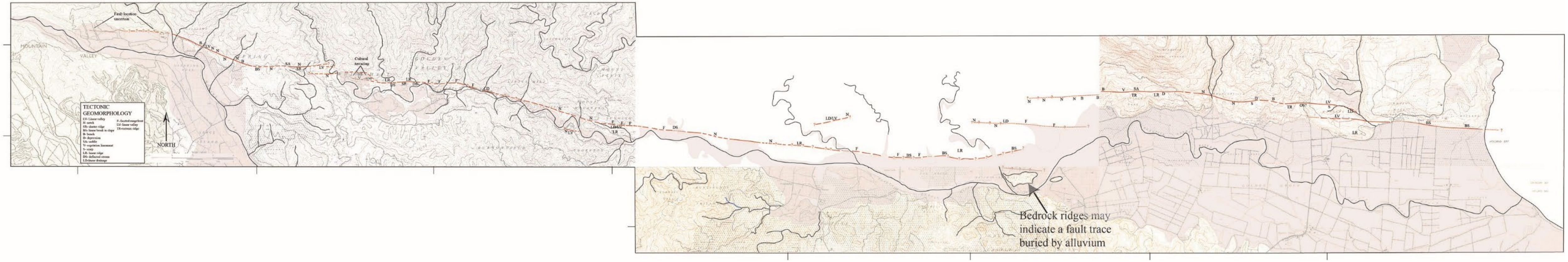
Bulletin of the Seismological Society of America, Vol. 103, No. 2A, pp. 971–983, April 2013, doi: 10.1785/0120120215

Enriquillo–Plantain Garden Fault Zone in Jamaica: Paleoseismology and Seismic Hazard

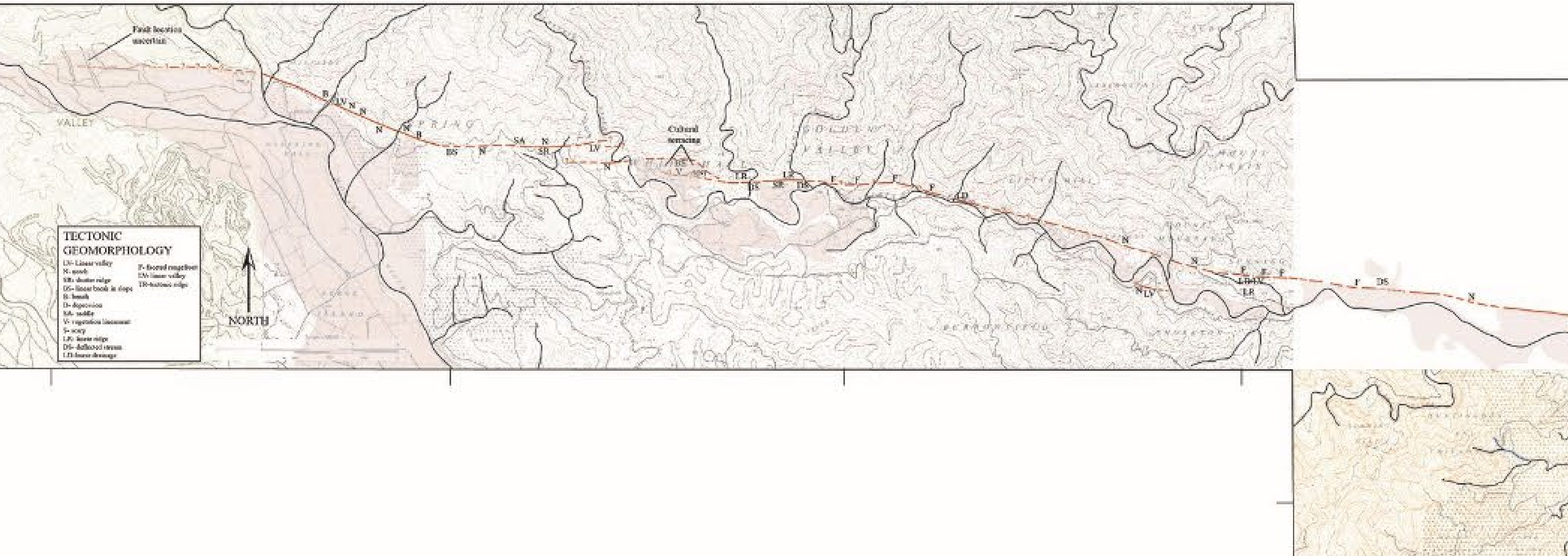
by R. D. Koehler, P. Mann, C. S. Prentice, L. Brown, B. Benford, and M. Wiggins-Grandison



PORTLAND PARISH
ST. THOMAS PARISH
Pentecostal City Mission Inc
Hayfield Primary School
Reggae Falls Travel & Tours
Blue Mountain Peak
Trinityville to Cedar Valley Rd
Trinity Ville
Hillside
White Hall Primary School
AnyMoney Supermarket
Ras kitchen & river side cool cabine
Bath Fountain
Bath
Bath Botanical Garden
Rowlandsfield Seventh Day Adventist Church
Lennox
Wheelerfield
Yap Variety Store
Amity Hal
Palm Royal Café
Font Hill Post Office
Font Hill
Prezi place
Seaforth
Middleton
B&D groceries
Danvers Pen
Wilmington District
Spring Garden
Airy Castle
Pear Tree River
Winchester
Golden Grove
Stokes Hall Great House
Duckenfield
A4
7 Eleven
Lennox
Wheelerfield Seventh Day Adventist Church
Wheelerfield
Yap Variety Store
Amity Hal
Garden
Palm Royal Café
A4

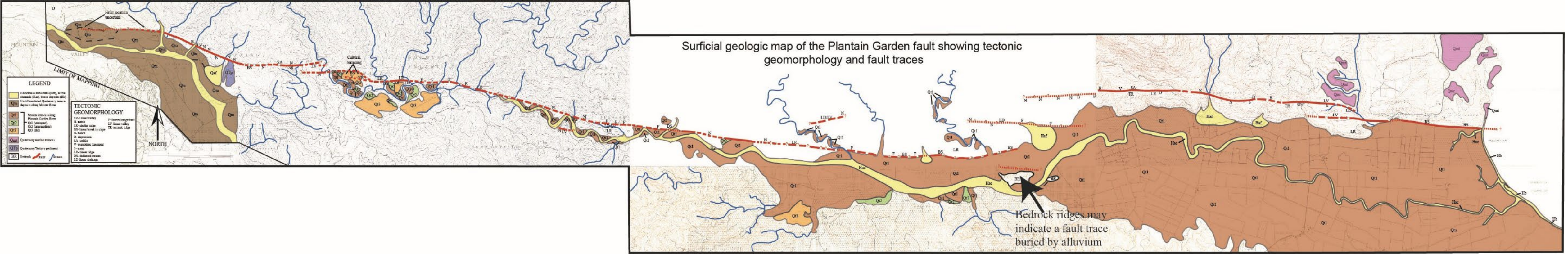


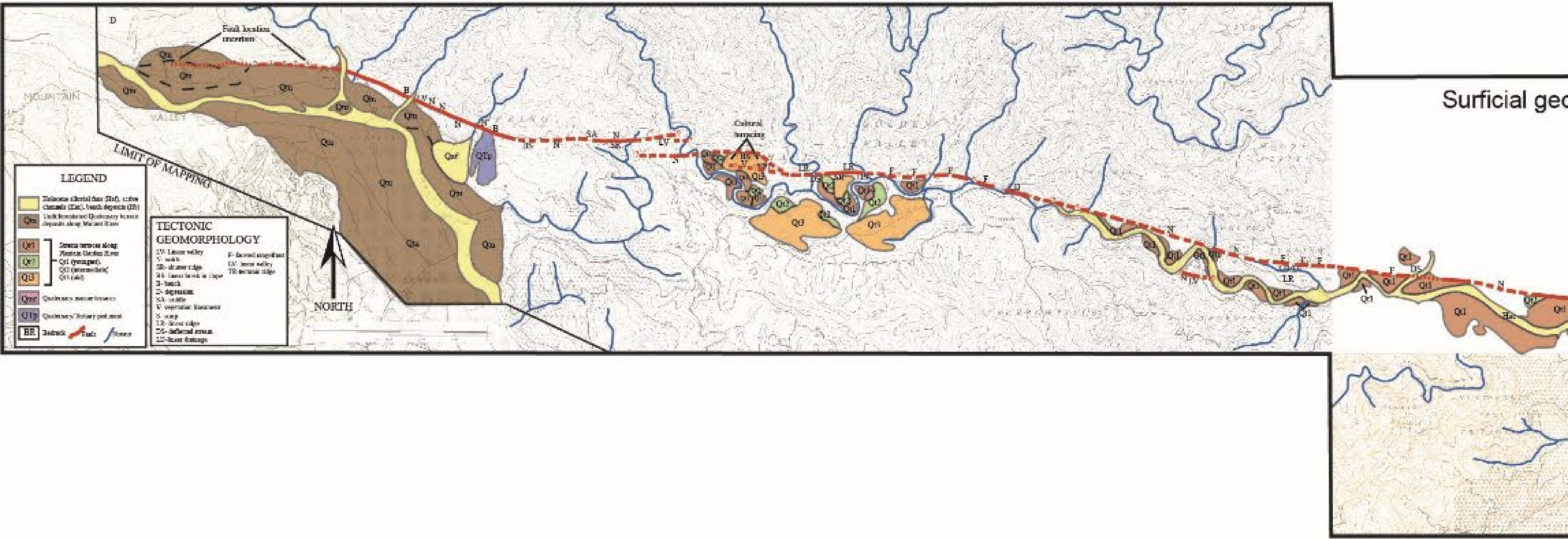
Fault location uncertain
MOUNTAIN
VALLEY
Cultural terracing
TECTONIC GEOMORPHOLOGY
NORTH
Bedrock ridges may
indicate a fault trace
buried by alluvium



Fault location uncertain
VALLEY
Cultural terracing
TECTONIC
GEOMORPHOLOGY
NORTH

Reggae Falls
avel & Tours
Blue Mountain Peak
Hayfield Primary School
Hillside
White Hall
Primary School
Ras kitchen & river
side cool cabine
AnyMoney Supermarket
Seaforth
Soho Square
Middleton
SERGE ISLAND
Seaforth Main St
B&D groceries


Surficial geologic map of the Plantain Garden fault showing tectonic geomorphology and fault traces
Bedrock ridges may indicate a fault trace buried by alluvium
LEGEND
TECTONIC GEOMORPHOLOGY
NORTH
LIMIT OF MAPPING


Fault location uncertain
Cultural terracing
LIMIT OF MAPPING
LEGEND
TECTONIC GEOMORPHOLOGY
NORTH
MOUNTAIN
VALLEY

Heuristics by demonstration: examples of fault maps: Hayward Fault prototype GIR
And two other Northern California examples

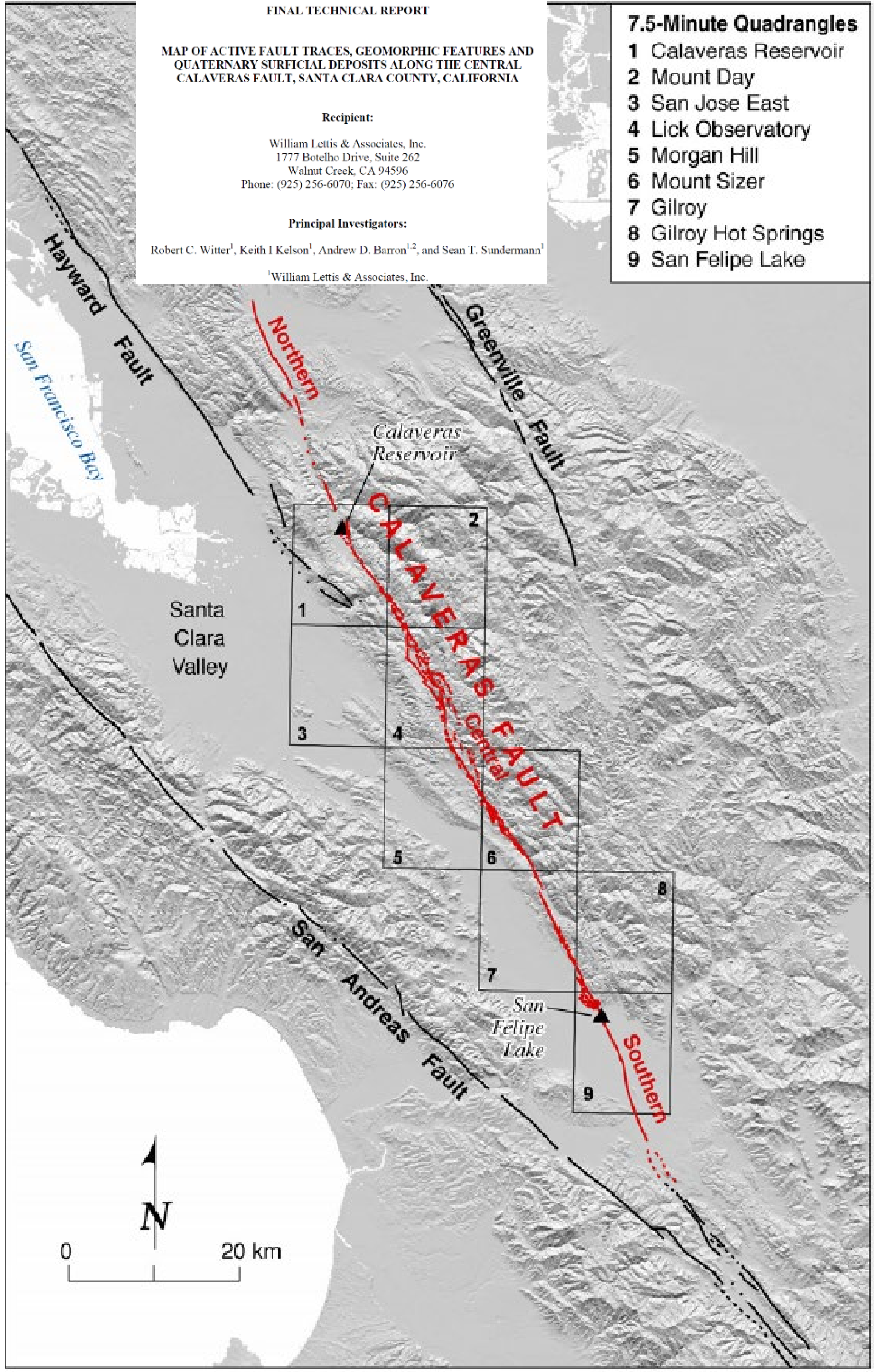
Geomorphic features are ranked according to a scale of clarity by using the following codes:
G1 indicates strongly pronounced features;
G2 indicates distinct features;
G3 indicates features with weaker expression.
Features of uncertain tectonic origin are queried.

The geomorphic codes do not reflect the degree of confidence in the judgement that particular fault traces are of Holocene age. Instead, where evidence for Holocene displacement is less certain, the map delineates the fault trace as a dotted line or queried dotted line.

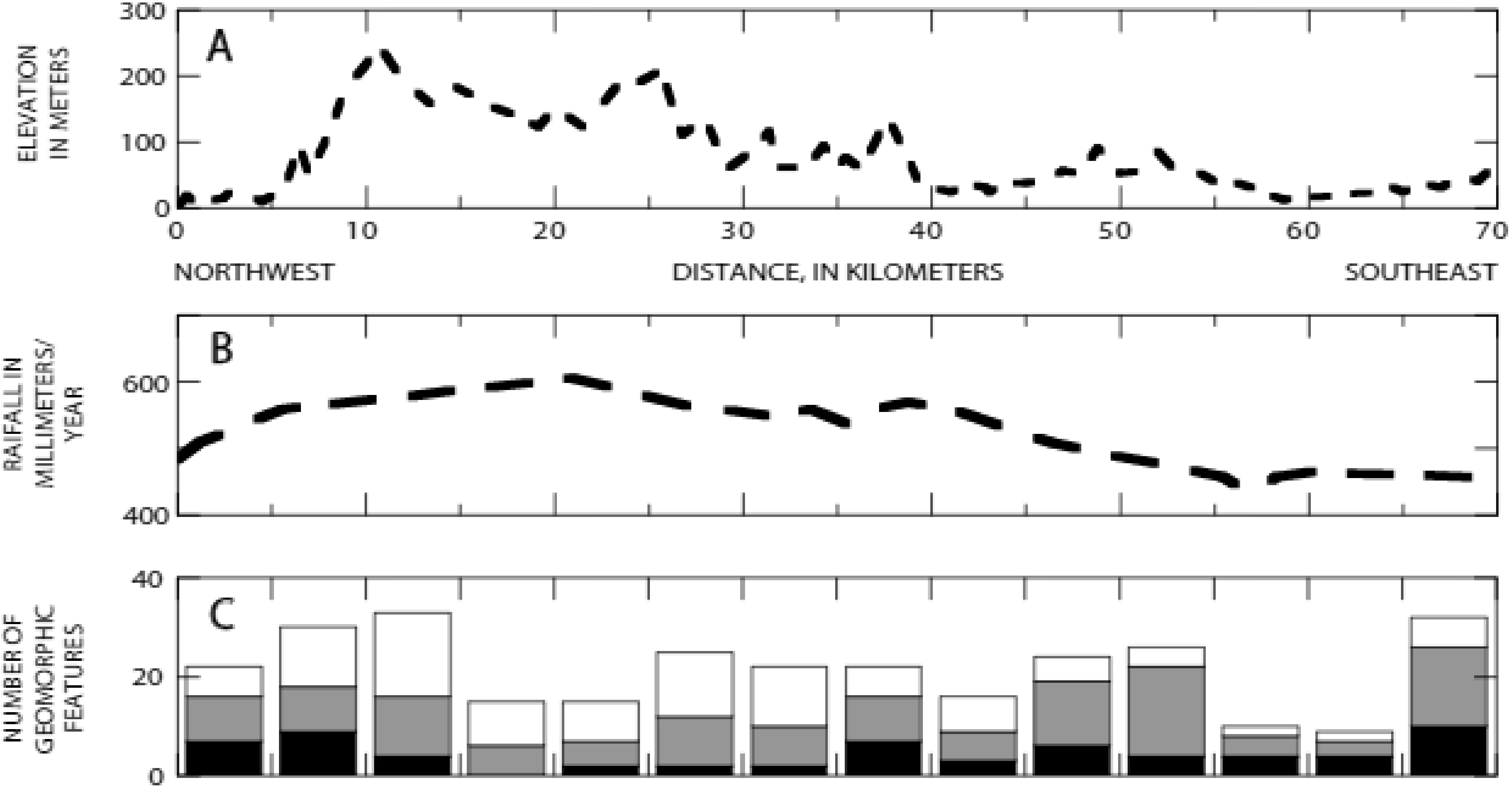
The accuracy of active fault locations relates to the clarity of geomorphic expression as well as any additional lines of evidence that accurately delineate the fault. For example, sections of the fault characterized by strongly pronounced and distinct features (G1 or G2) that coincide with creep evidence and/or geological evidence for Holocene displacement can be more accurately located than ambiguous fault traces defined by weakly expressed features that lack evidence for creep or geologic information derived from paleoseismic trenches.

Uncertainty in the location of fault traces is expressed by varying line types in the following way: (1) solid lines indicate well located traces (≤±25 m); (2) dashed lines indicate traces located with less certainty (≤±50 m); and (3) dotted lines indicate concealed or inferred fault traces (≤±75 m).

Follows Lienkaemper, J.J., 1992, Map of recently active traces of the Hayward Fault, Alameda and Contra Costa Counties, California: U.S. Geological Survey Miscellaneous Field Studies Map MF-2196, map scale 1:24,000, 13 p.



Quality assessment



Hayward fault-related geomorphic features (black, G1; dotted, G2; white, G3) (Lienkaemper, 1992)

https://www.researchgate.net/publication/237789684_Map_of_recently_active_traces_of_the_Hayward_fault_Alameda_and_Contra_Costa_counties_California

FINAL TECHNICAL REPORT

DIGITAL COMPILATION OF NORTHERN CALAVERAS FAULT DATA FOR THE NORTHERN CALIFORNIA MAP DATABASE: COLLABORATIVE RESEARCH WITH WILLIAM LETTIS & ASSOCIATES, INC., AND THE U.S. GEOLOGICAL SURVE

Recipient:

William Lettis & Associates, Inc.
1777 Botelho Drive, Suite 262
Walnut Creek, CA 94596

Principal Investigators:

Keith I. Kelson and Sean T. Sundermann

121°55'9"W

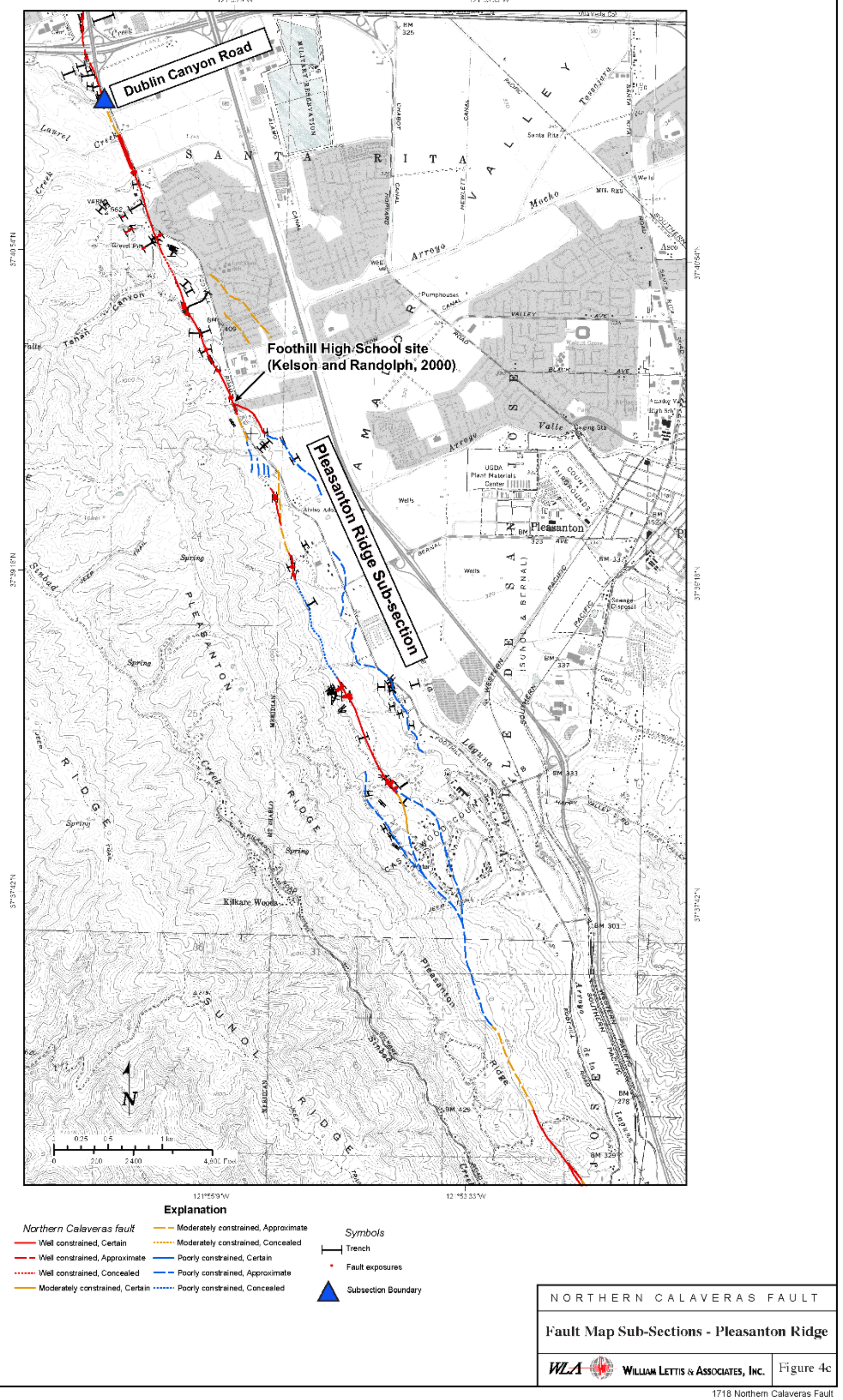
Explanation

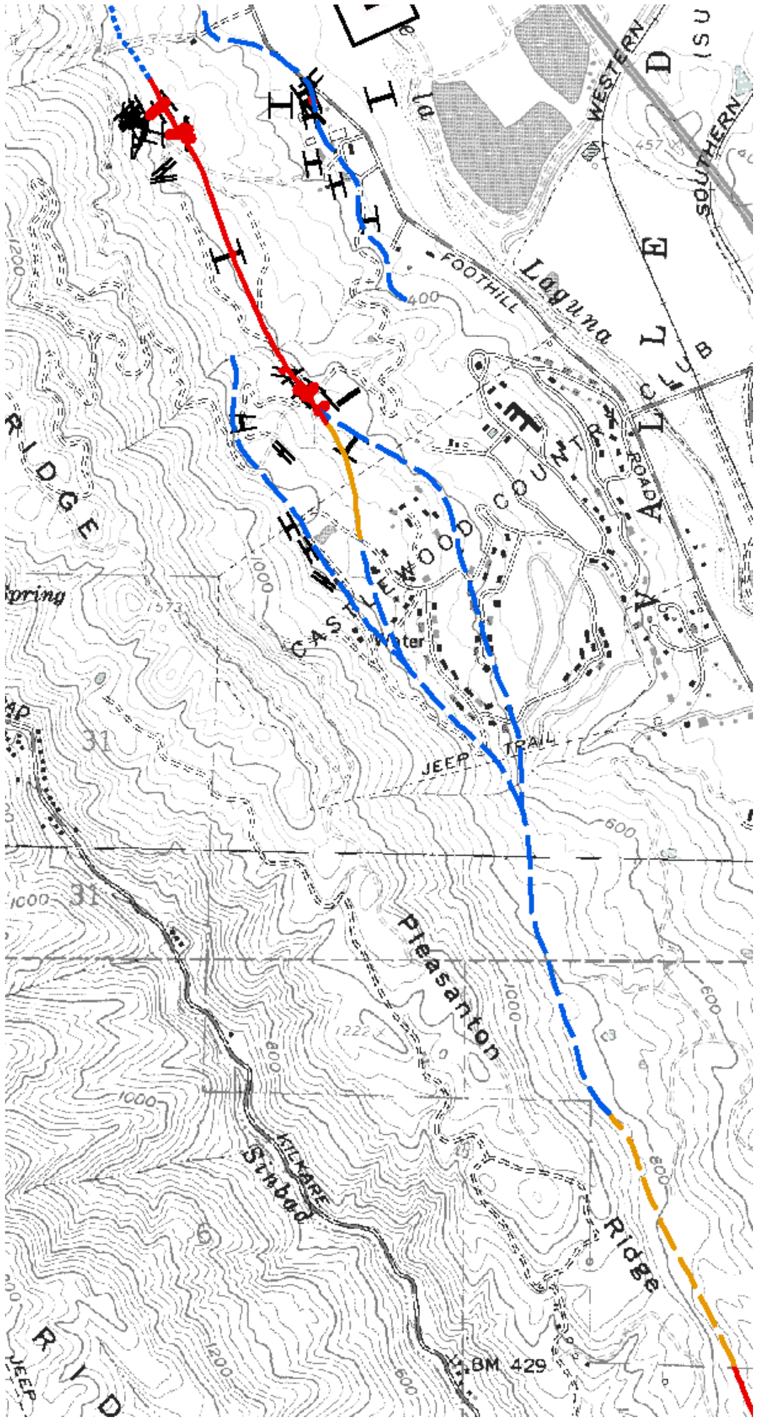
Northern Calaveras fault

- Well constrained, Certain
- Well constrained, Approximate
- Well constrained, Concealed
- Moderately constrained, Certain
- Moderately constrained, Approximate
- Moderately constrained, Concealed
- Poorly constrained, Certain
- Poorly constrained, Approximate
- Poorly constrained, Concealed

Symbols

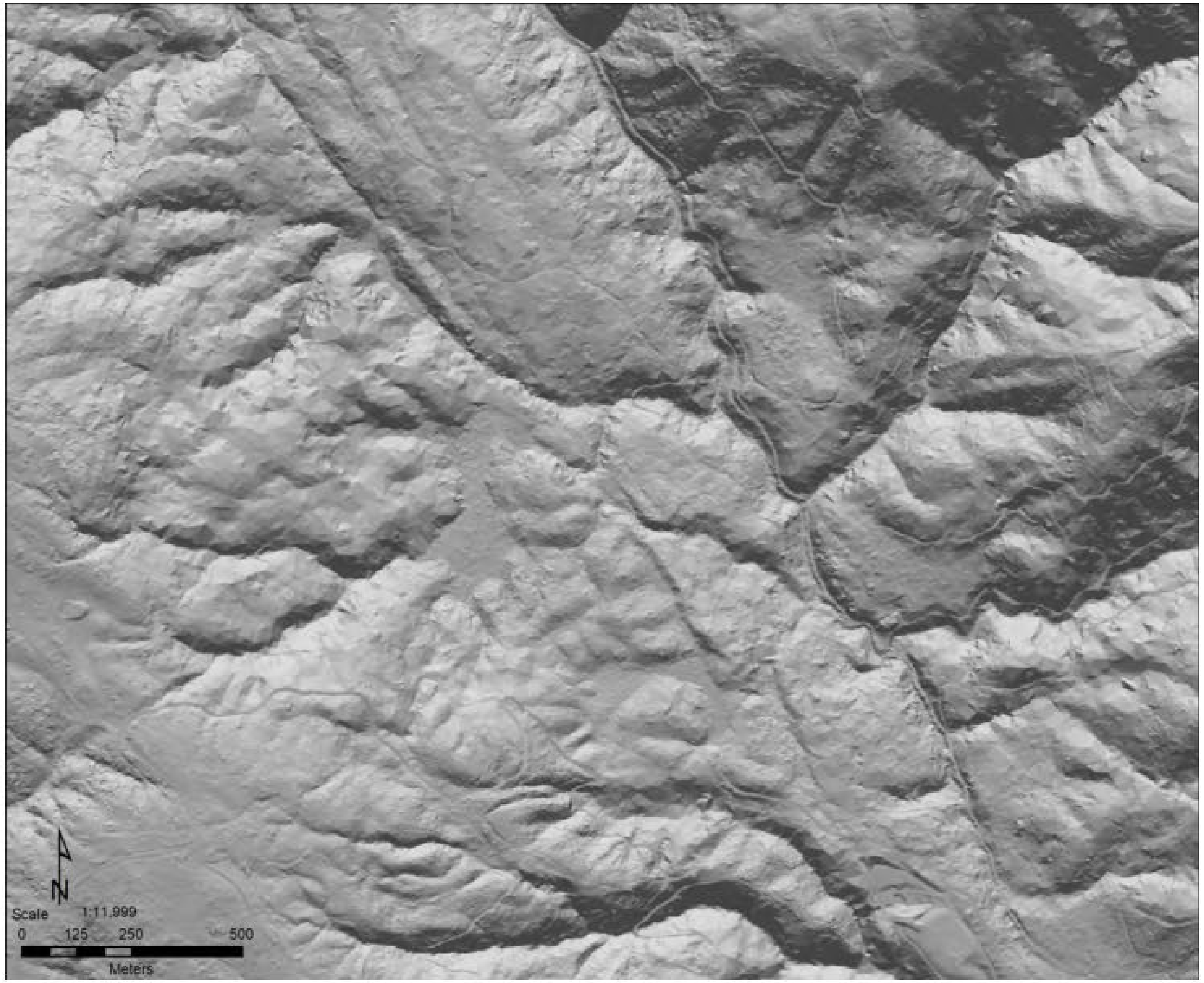
- Trench
- Fault exposures
- Subsection Boundary

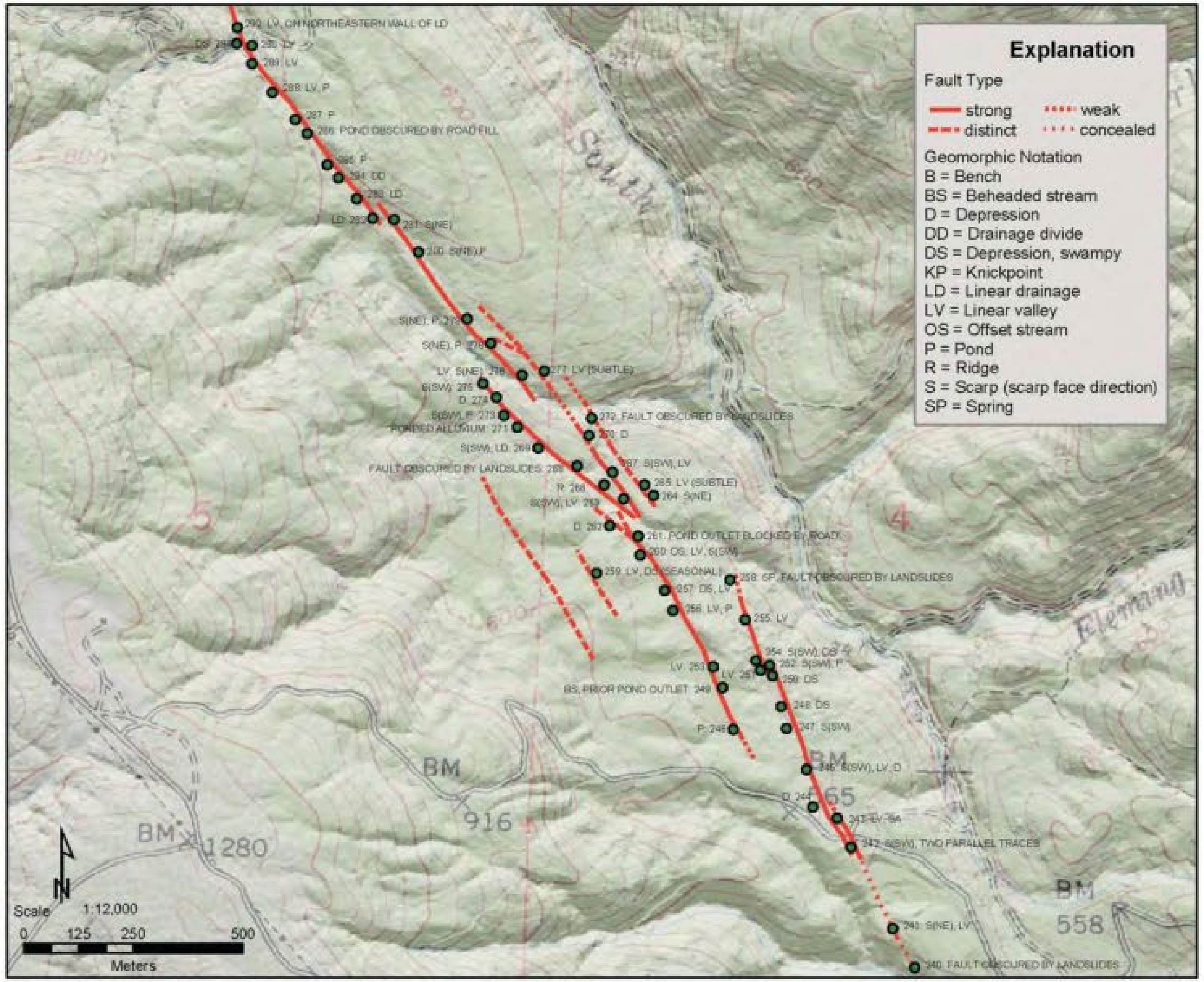




line types and geomorphic indicators

Lidar and field mapping, northern San Andreas fault

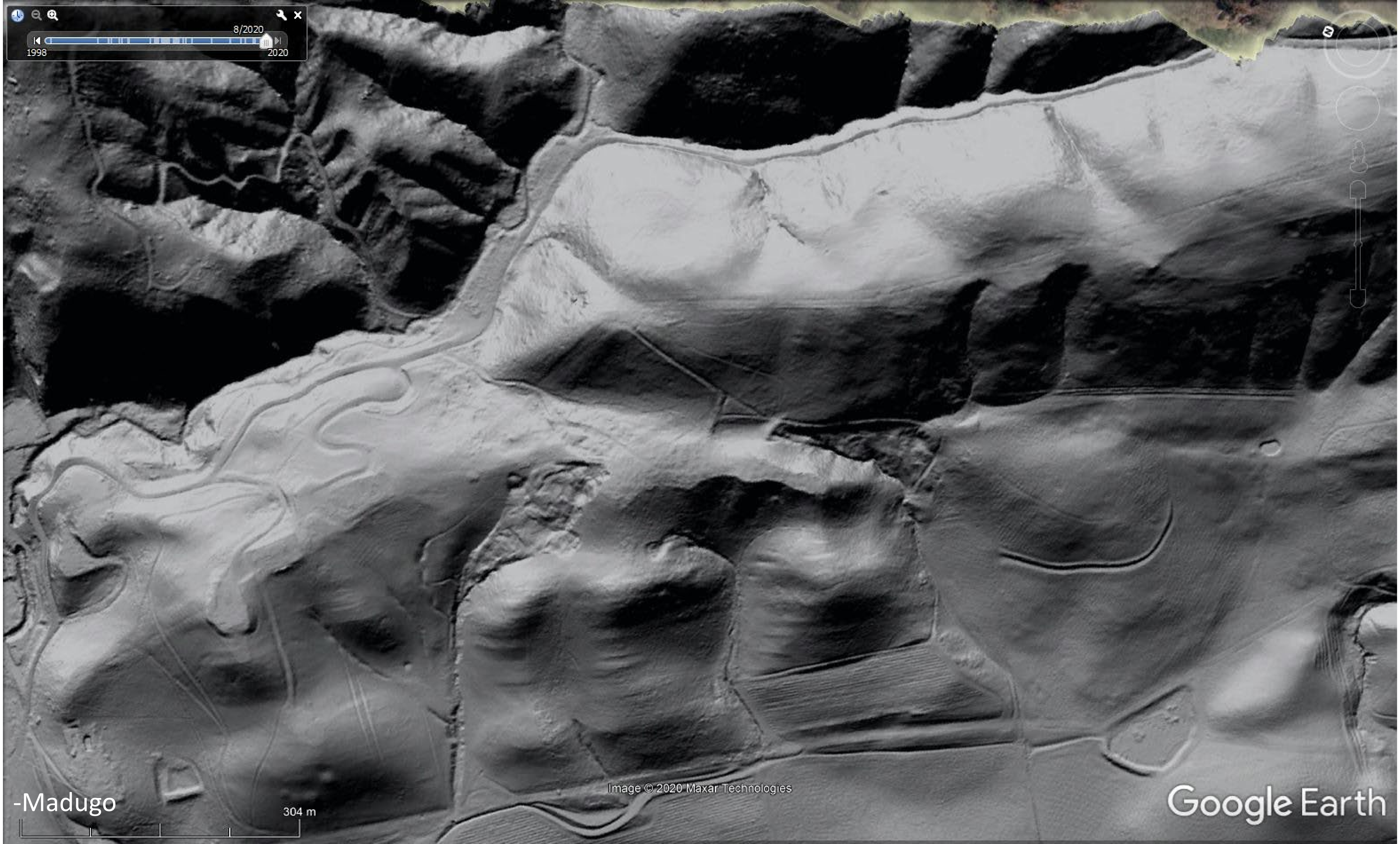


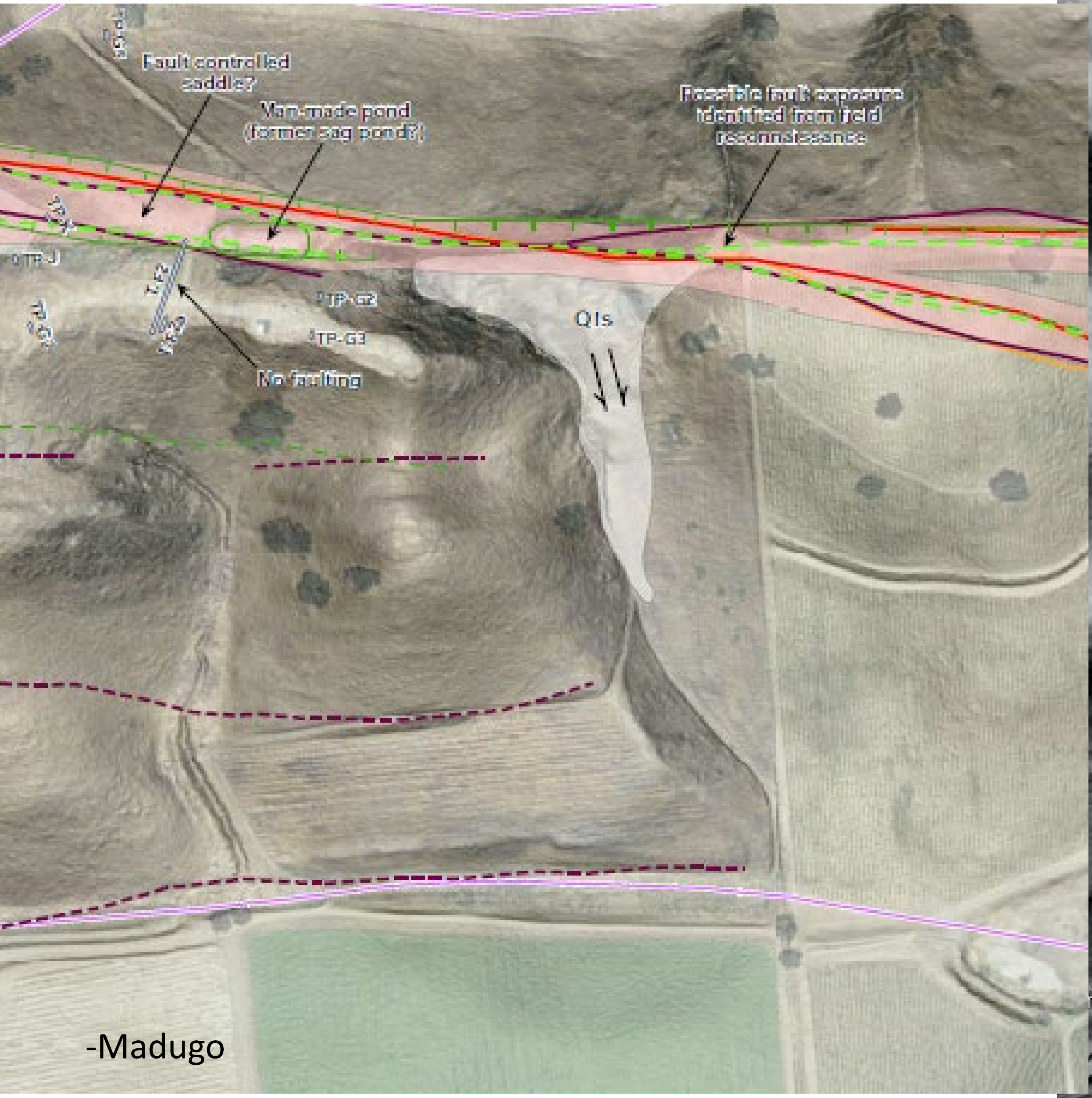


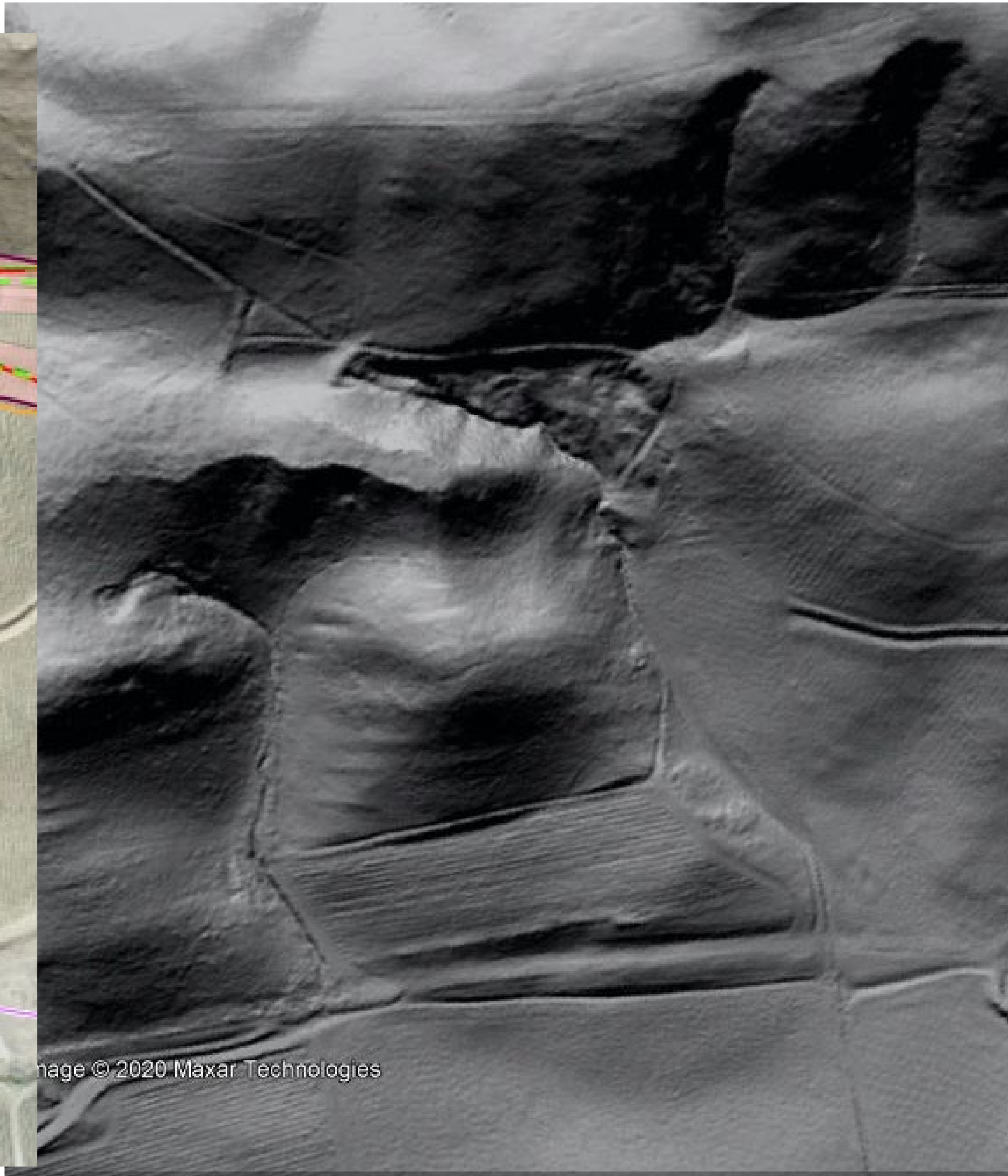
http://activetectonics.asu.edu/mapping_active_faults/Lectures/Strike_slip_koehler_2_10_22.pdf

Heuristics by demonstration: examples of fault maps: Calaveras Fault


Consistency of features observed along strike at different scales, yet still have good examples of uncertainty (e.g. which side of a trough or valley does the main strand go).
Calaveras Fault
9-20 mm/yr
Creeping
3/2018
-Madugo
304 m
Google Earth


8/2020
1998
2020
Image © 2020 Maxar Technologies
-Madugo
304 m
Google Earth


Fault controlled saddle?
Man-made pond (former sag pond?)
Possible fault exposure identified from field reconnaissance
TP-J
TP-G2
TP-G3
No faulting
Qls
-Madugo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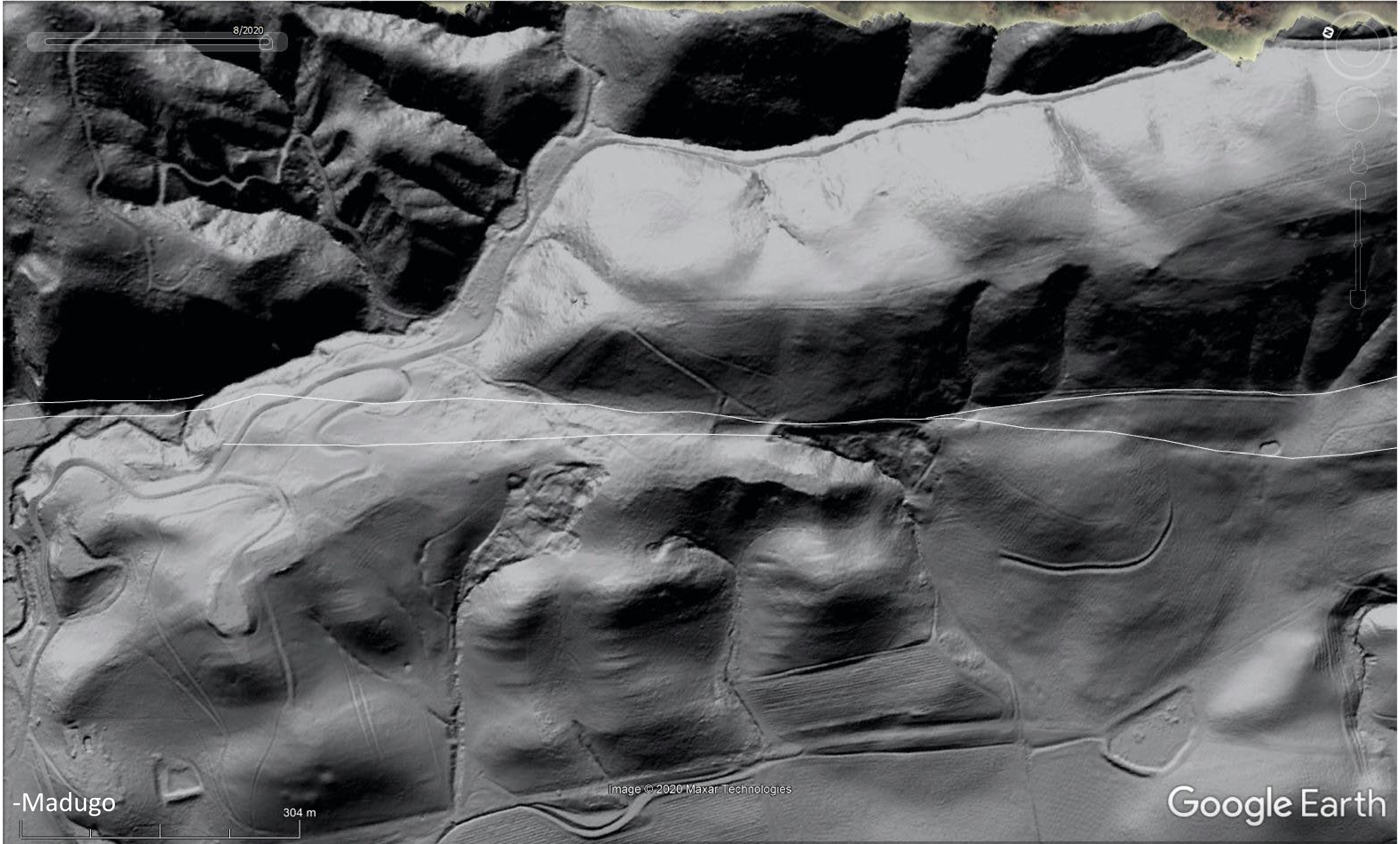
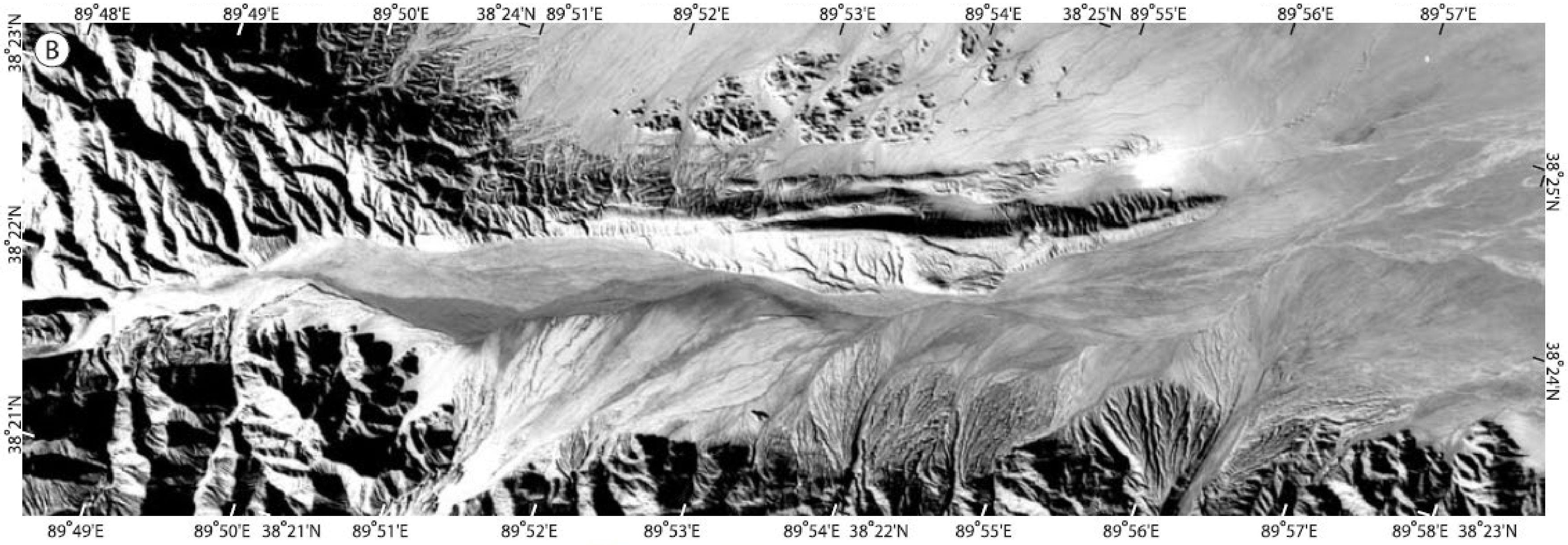
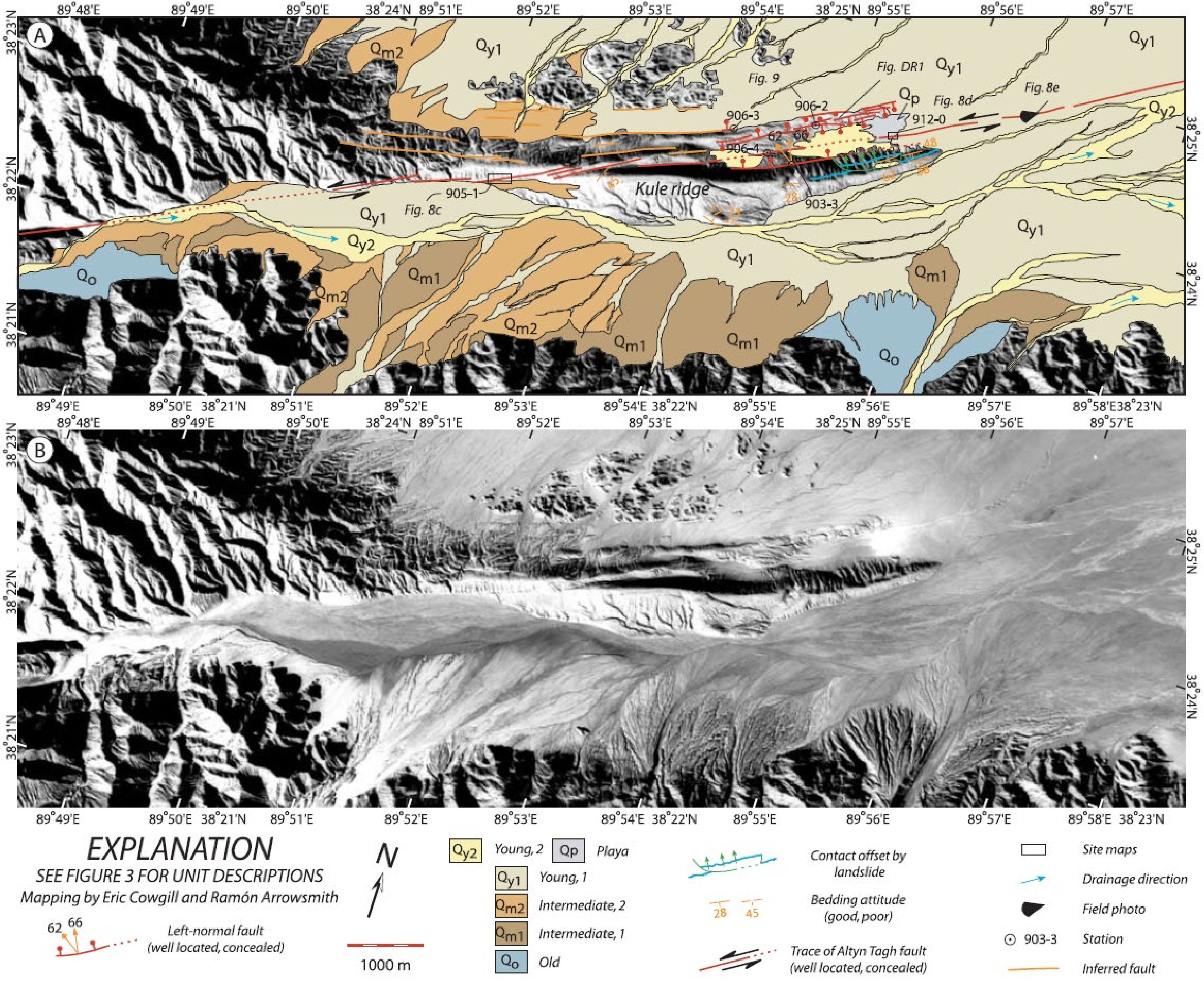

8/2020
Image © 2020 Maxar Technologies
-Madugo
304 m
Google Earth

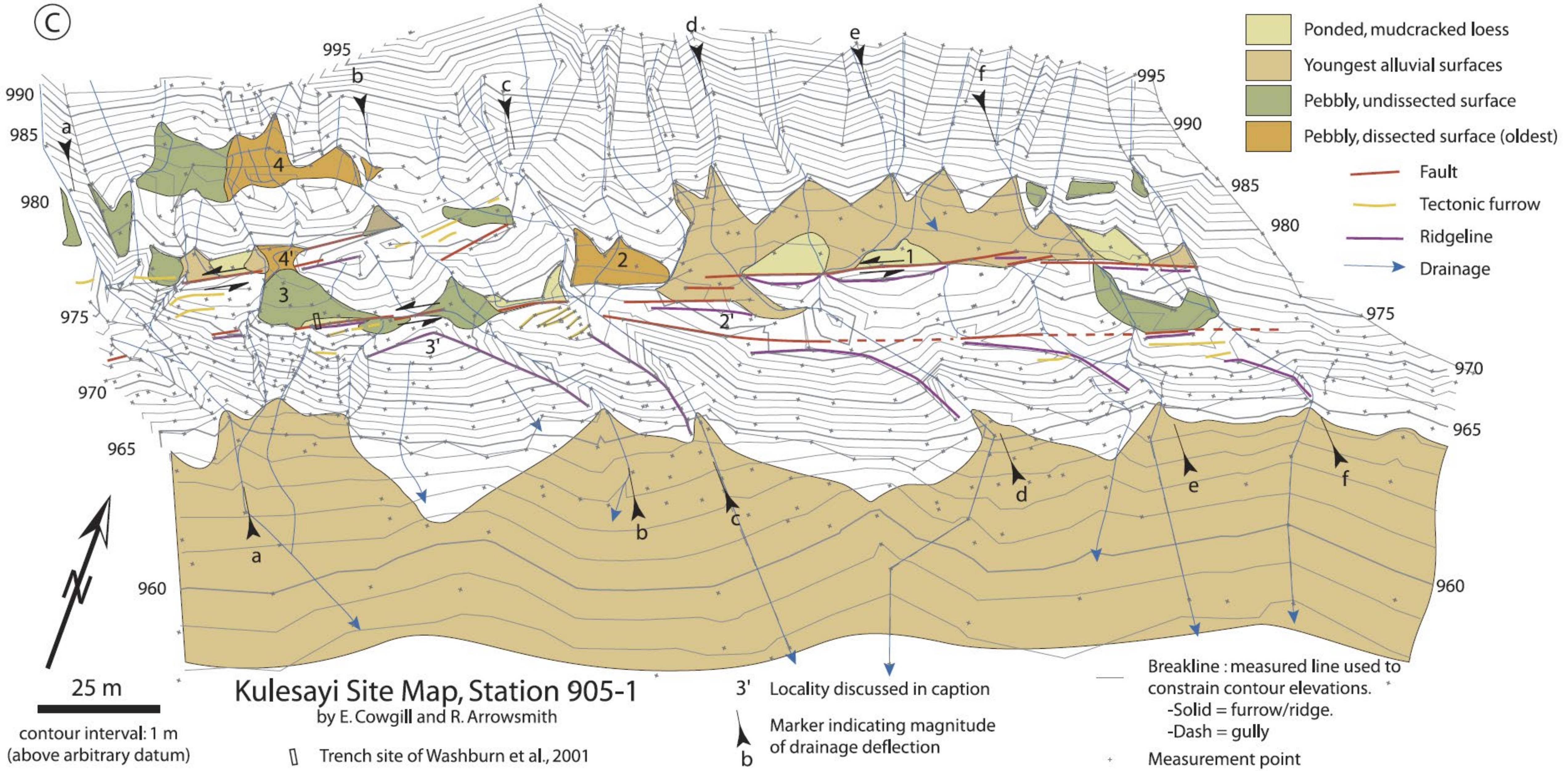
3/2018
-Madugo
304 m
Google Earth

Altyn Tagh Fault, Xinjiang China



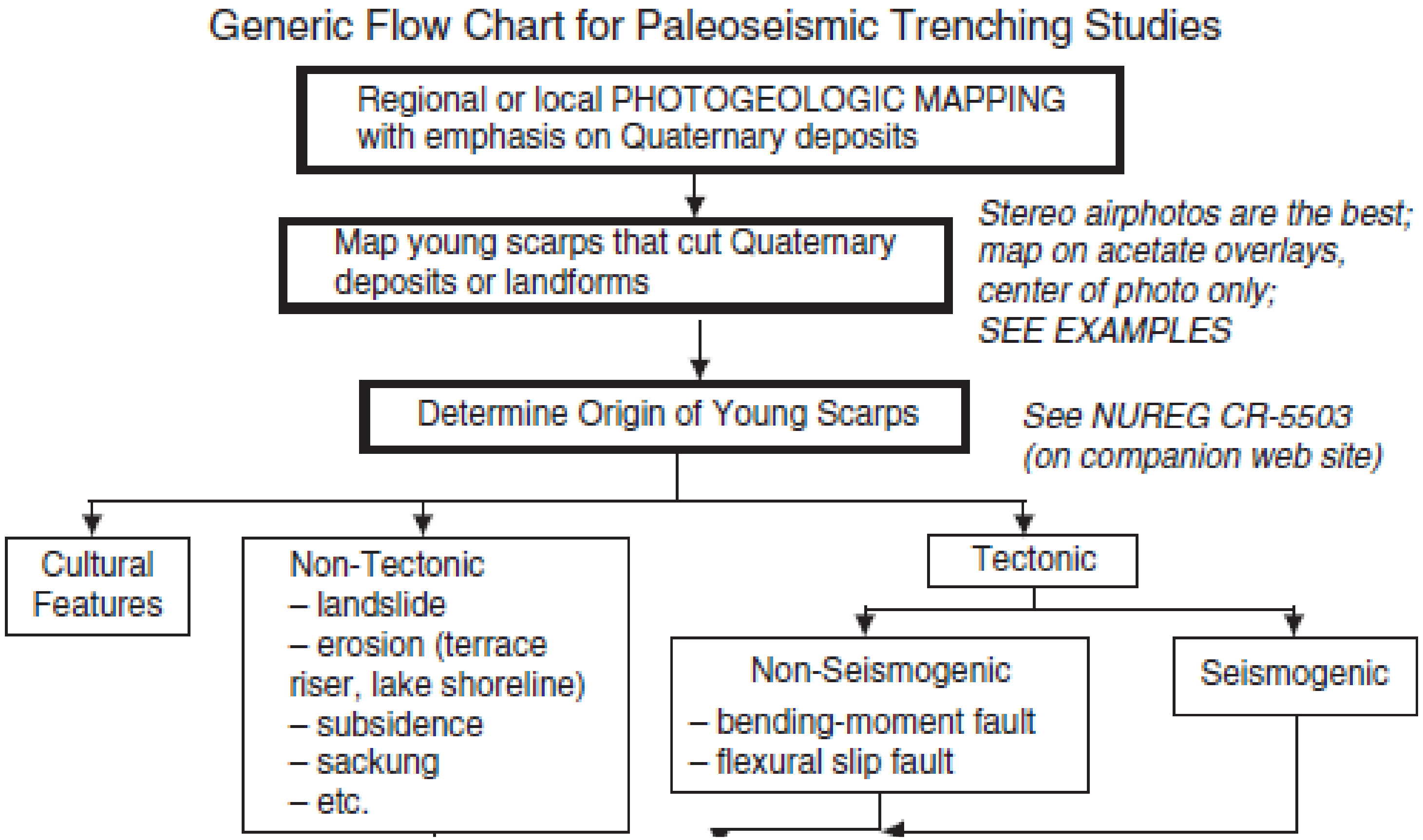


Cowgill, E. Arrowsmith, J R., Yin, A., Xiaofeng, W., Zhengle, C., The Akato Tagh bend along the Altyn Tagh fault, NW Tibet 2. Active deformation and the importance of transpression and strain-hardening along the Altyn Tagh system, Geological Society of America Bulletin, 116, p. 1443--1464, 2004.



C
Ponded, mudcracked loess
Youngest alluvial surfaces
Pebbly, undissected surface
Pebbly, dissected surface (oldest)
Fault
Tectonic furrow
Ridgeline
Drainage
995
990
985
980
975
970
965
960
a
b
c
d
e
f
1
2
2'
3
3'
4
4'
25 m
contour interval: 1 m
(above arbitrary datum)
Kulesayi Site Map, Station 905-1
by E. Cowgill and R. Arrowsmith
Trench site of Washburn et al., 2001
3' Locality discussed in caption
Marker indicating magnitude of drainage deflection
Breakline : measured line used to constrain contour elevations.
-Solid = furrow/ridge.
-Dash = gully
Measurement point

Mapping flow charts, workflow, schemas



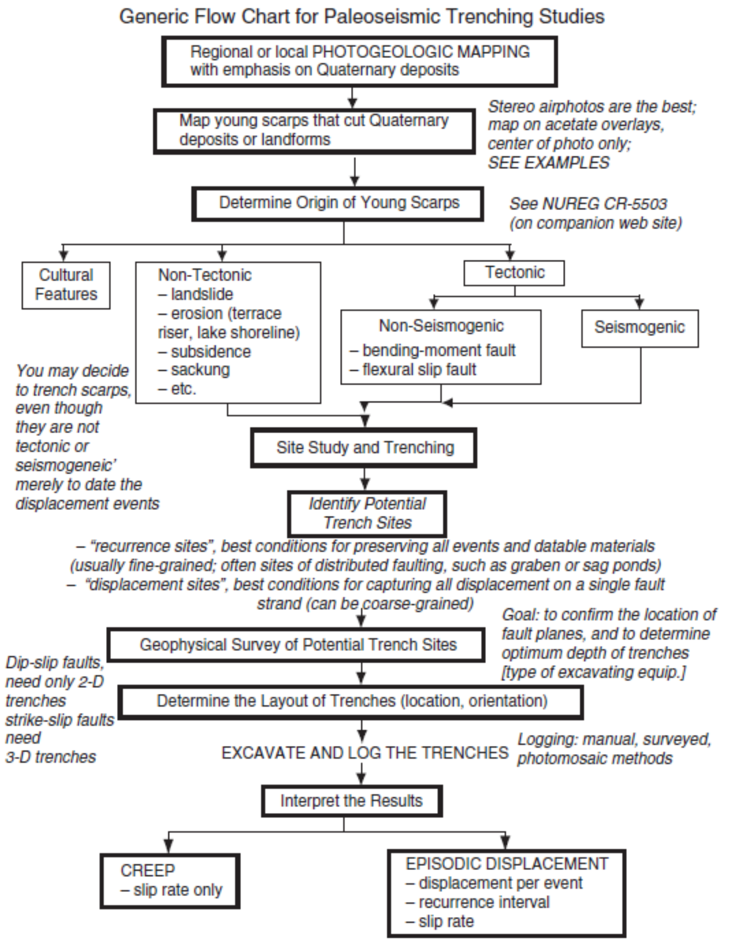


Figure 2A.1: A generic sequence of paleoseismic investigations that ends in trenching a young fault scarp. NUREG CR-5503 refers to Hanson *et al.* (1999).

McCalpin textbook

Locational Accuracy and Scientific Confidence

California Department of Conservation

- Terms come from USGS geologic mapping standards (See Soller et al. (2002) – USGS OFR 02-370)

Scientific confidence:

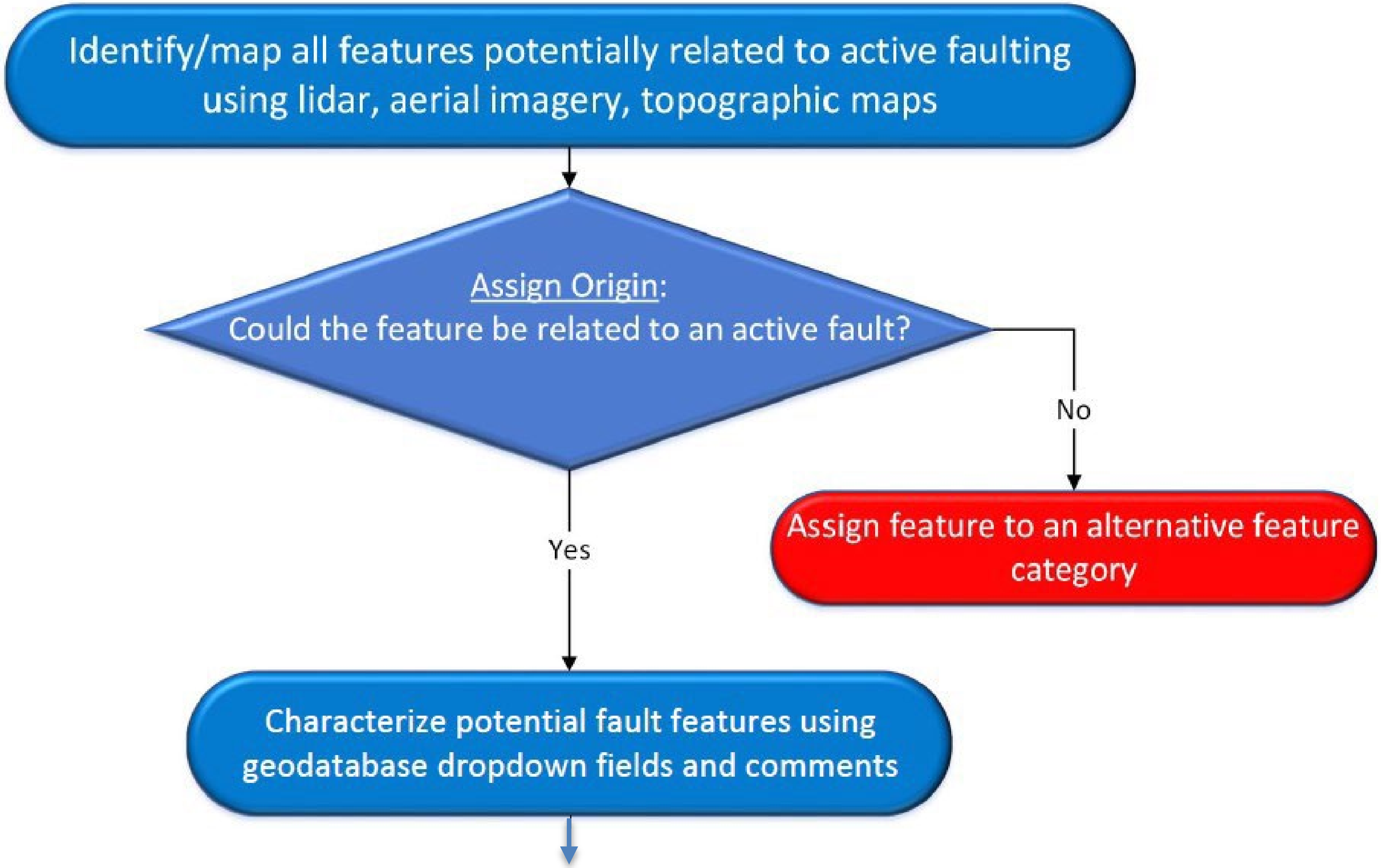
  - Identity: What is the feature?
  - Existence: How confident are we what it is?

- Locational accuracy: Can I plot with feature accurately?
- Inferred and concealed categories are more interpretive.

Symbol	Scientific confidence	Examples
——————— — — — — — - - - - - - - - - -	Identity and Existence certain	*"I am certain that the planar feature I see in this outcrop is a fault."*
———?——— — — —?— — — - - ?- - ?- - ?- - ....?....?....?....	Identity or Existence questionable	*"I can see some kind of planar feature in this outcrop, but I can't be certain if it's a contact or a fault."*

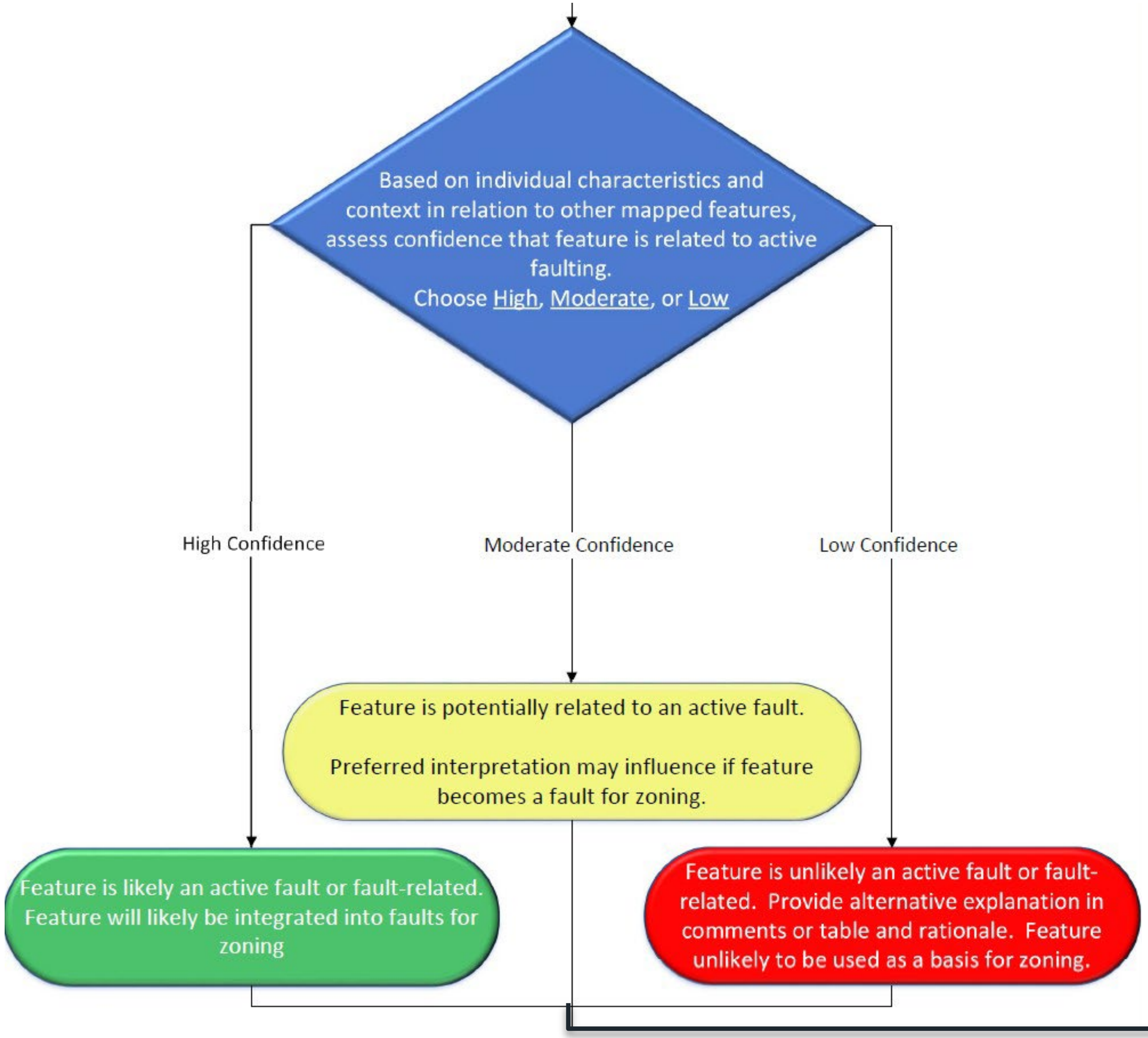
Symbol	Locational accuracy	Examples
———————	accurately located	*"I can clearly see this contact in outcrop, and can accurately plot its position on the map."*
— — — — —	approximately located	*"I can see this contact in outcrop, but the poor quality of my base map prohibits me from accurately plotting its position."*
- - - - - - - - - -	inferred	*"I can see by the change in debris materials visible around these gopher holes that a contact runs through here, but I can't locate it very precisely."*
....	concealed	*"I can see that a contact is present on both sides of this lake, but I can't tell where it is located beneath the water."*

Typical CGS Workflow for Active Fault Mapping



Typical CGS Workflow for Active Fault Mapping

California
Department of Conservation



- High, moderate, low categories are relative.
  - Advisable to have some examples from the project area illustrating how you, as the mapper, assign the categories.

- Context is important. A single feature, for example, a spring may have a low-confidence rating that it is fault related. However, put into the context with other features (on-trend vegetation lineaments), the same feature may be assigned a high-confidence rating.

Geodatabase Schema

- Geodatabase can be as simple or as complex as desired. The level of complexity depends on what the geodatabase will be used for and should consider what is practical in terms of time and effort to populate. Fields with specified values typically reserved for DB queries and symbology.

Type	Specifies the kind of feature represented by the line. For example, "fault", ”scarp” “vegetation lineament", “linear ridge", etc. Can be populated with dropdown values. Nulls not permitted
Location Confidence	Half-width in meters of positional uncertainty envelop; position is relative to other features in database. Null values not permitted. Recommend value of -9 if value is not available. Suggested distances qualitatively described in "Feature-level metadata" document
Existence Confidence	Values = "certain", "questionable", "unspecified". Null values not permitted. Suggest setting default value to "certain"
Identity Confidence	Values = "certain", "questionable", "unspecified“. Alternative: “High”, Moderate”, “Low”. Null values not permitted. Suggest setting default value to "certain"
Data Source	Imagery used for interpretation, e.g. NCALM lidar, NAIP, 1:5,000 airphotos
Mapping scale	Mapping scale of either linework, or project (if set mapping scale used).
Comments	Optional. Free text for additional information specific to this feature. Null values permitted.
Mapper	Name of mapper
Mapper Affiliation	Affiliate of mapper, commonly recognized abbreviations (e.g. CGS, USGS, UNR) acceptable.

Feature Classes

What feature class to use is often scale-dependent.

- Lines: Linear features such as faults, tonal lineaments, linear valleys, deflected drainages

- Points: Smaller features such as springs, saddles, small depressions, places that you want to annotate with a comment

- Polygons: Larger features such as pull-apart basins, triangular facets, linear ridges/pressure ridges, offset surfaces.

Attribute fields

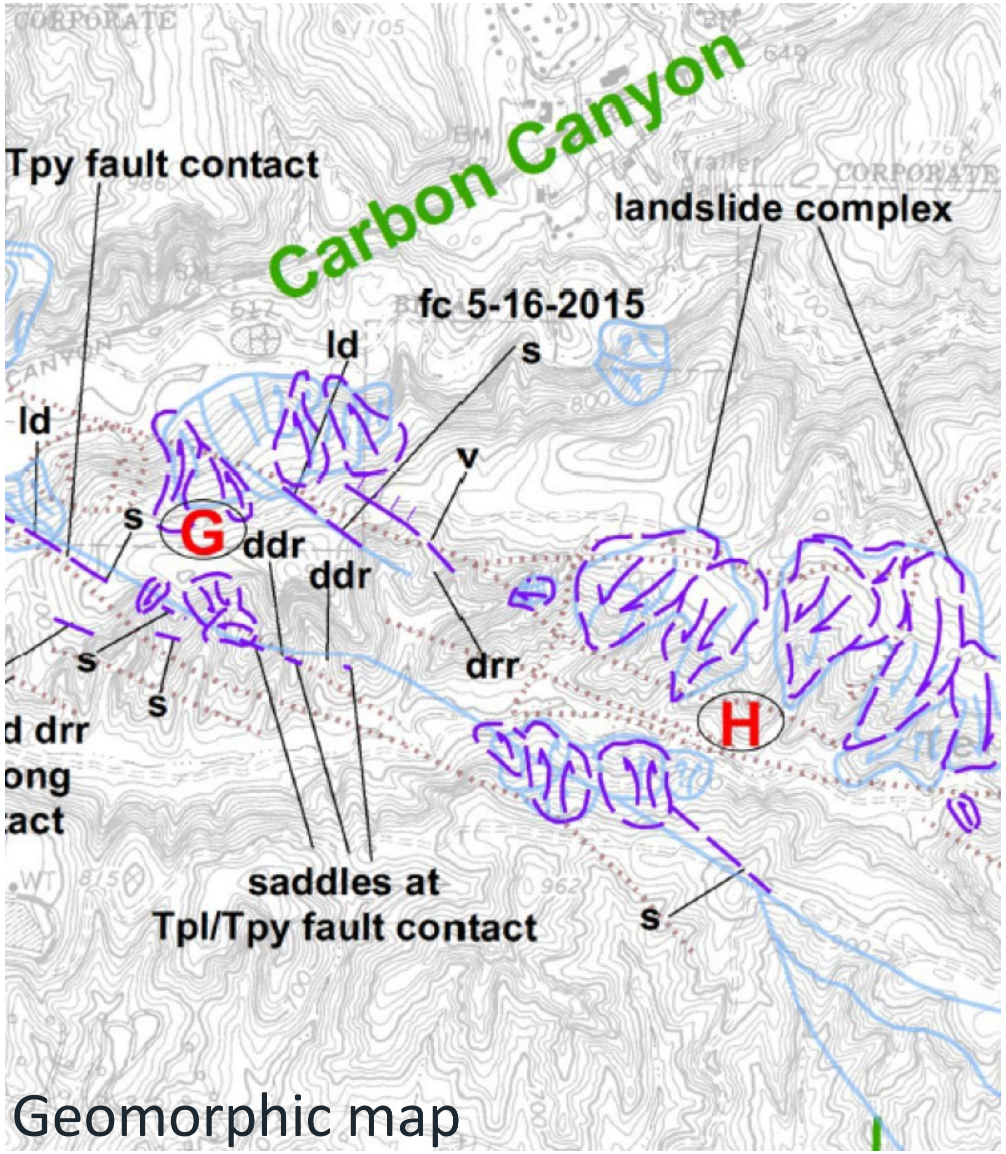
ArcGIS (not sure about QGIS) has the ability to have dropdown lists in the attribute fields that help enforce consistence and aids in filling out attributes.

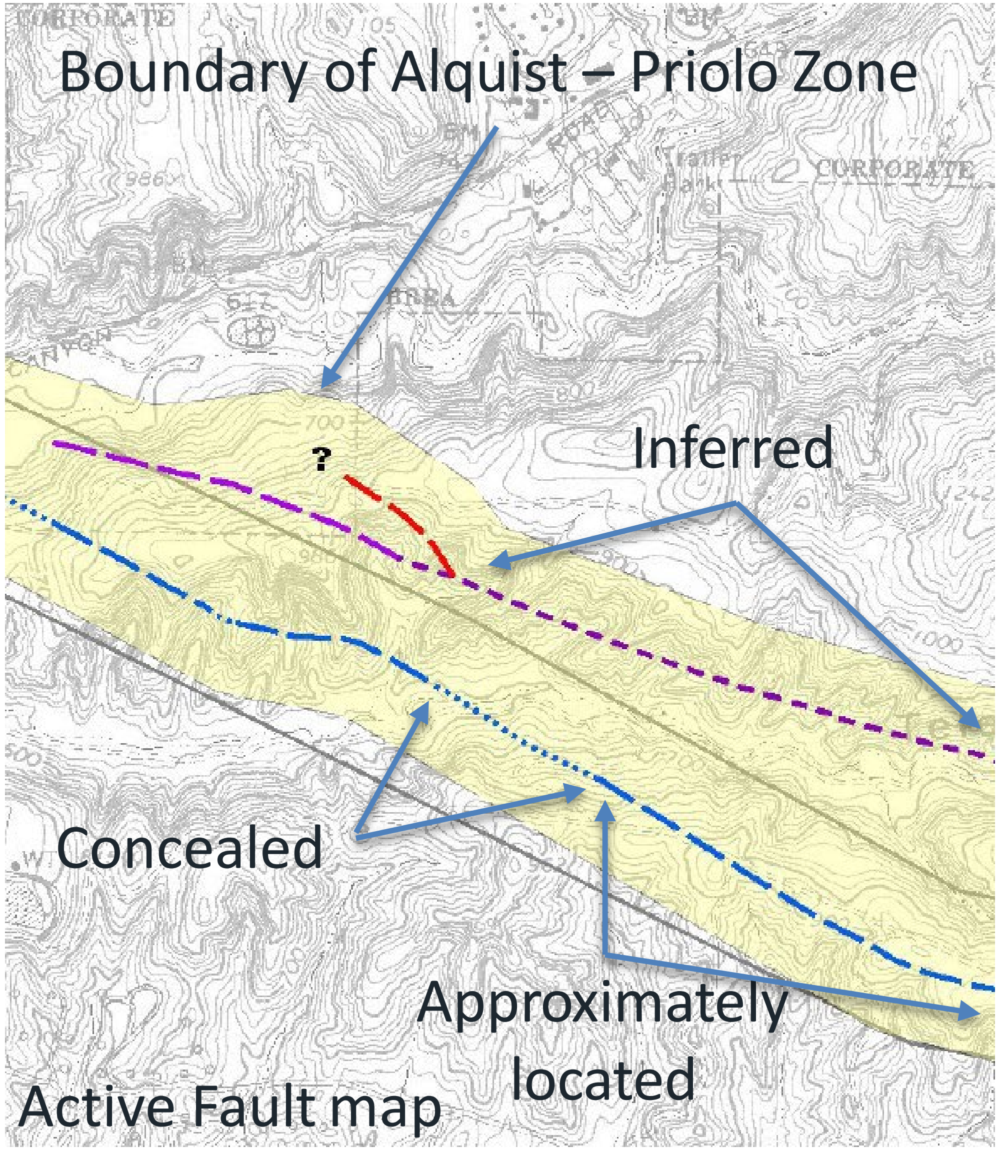
Some examples of what CGS uses:

- Type (Origin)

- Feature type Dropdown list
- Uphill-Facing Scarp
- Beheaded Drainage
- Break in Slope
- Closed Depression
- Deflected Drainage, left lateral
- Deflected Drainage, right lateral
- Drainage Knickpoint
- Faceted Spur
- Linear Drainage
- Linear Trough
- Notch
- Offset Cultural Feature
- Ponded Alluvium
- Pressure Ridge
- Offset Ridge, left lateral
- Offset Ridge, right lateral
- Saddle
- Scarp
- Shutter Ridge
- Side-Hill Bench
- Spring
- Swale
- Tonal Lineament
- Trough
- Vegetation Lineament
- Sag Pond
- Mole Track
- Linear Front
- Offset Drainage, right lateral

Example of CGS FER geomorphic map and A-P Zone map





From Hernandez (2017) CGS FER 258

Heuristics by demonstration: examples of fault maps: Geological Survey of Japan

中央構造線活断層系(四国地域)ストリップマップ

STRIP MAP OF THE MEDIAN TECTONIC LINE ACTIVE FAULT SYSTEM IN SHIKOKU

1:25,000

地 質 図	2
凡　　例	1
説 明 書	1

地　質　調　査　所

GEOLOGICAL SURVEY OF JAPAN

1-3, Higasi 1-chōme, Tsukuba-shi, Ibaraki-ken, 305 Japan

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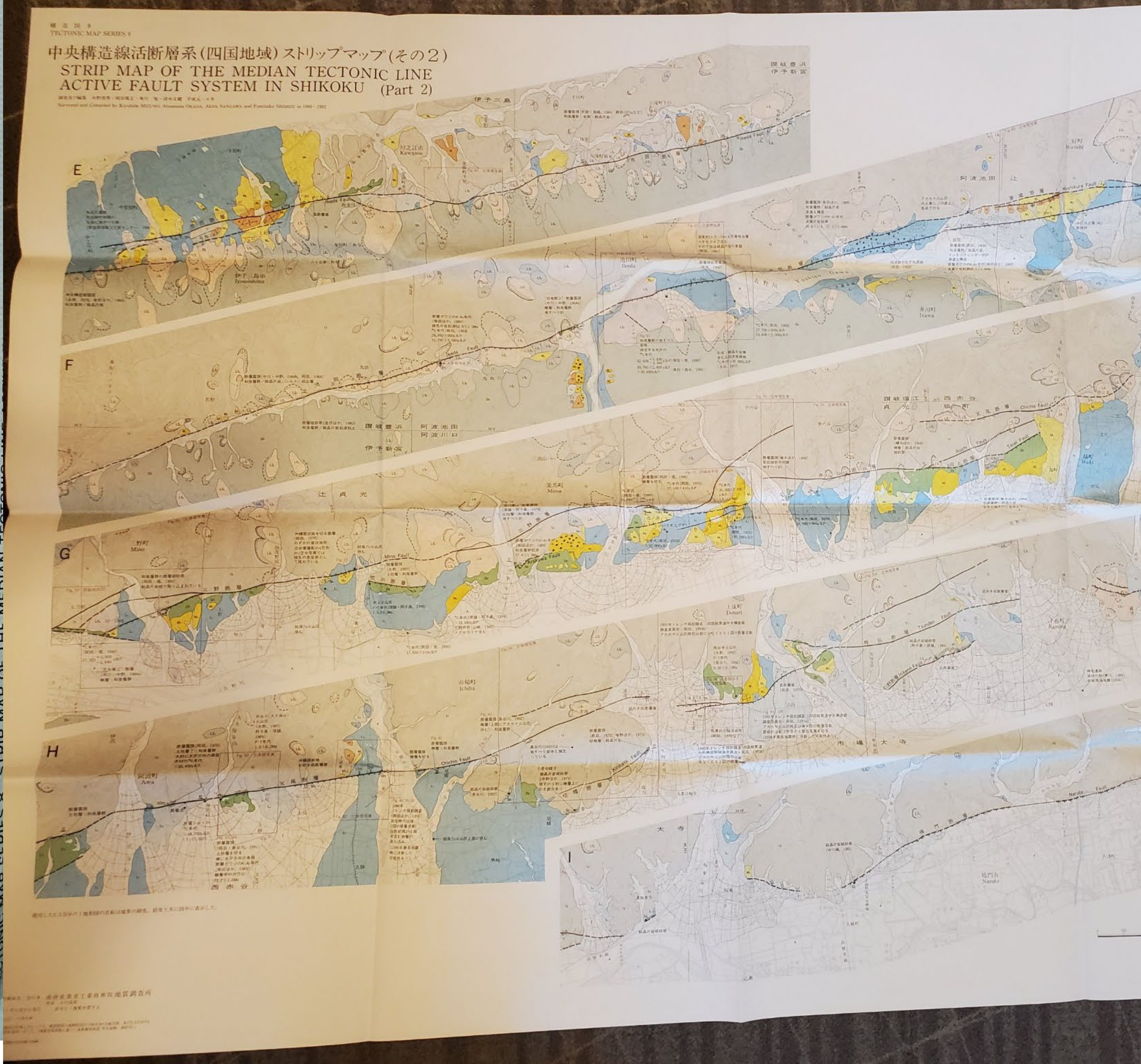
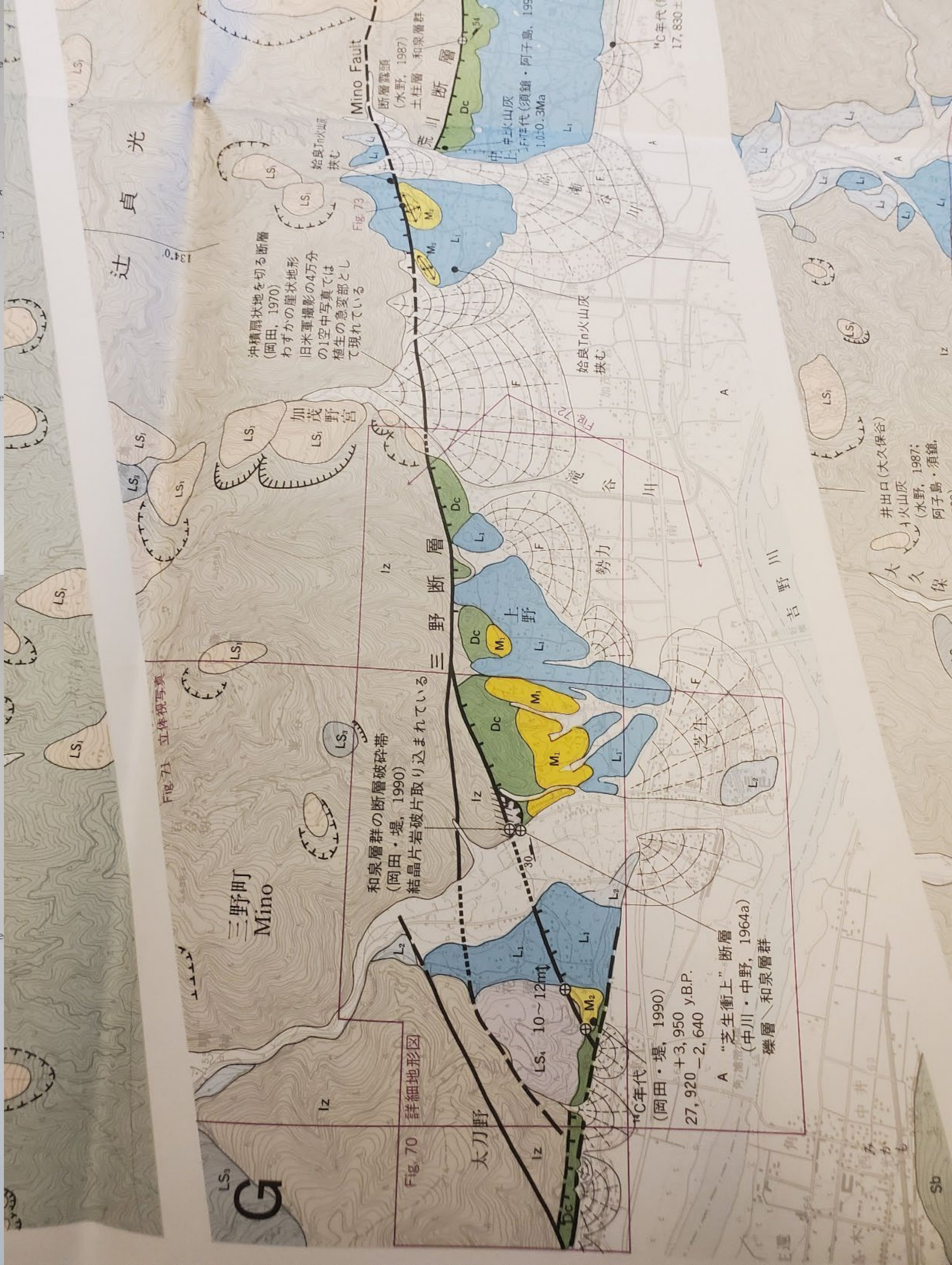


	埋立地 Reclaimed land	R	
完新世 Holocene	沖積層 Alluvium	A	礫，砂及びシルト Gravel, sand and silt
	沖積扇状地堆積物 Alluvial fan deposits	F	礫及び砂 Gravel and sand
後期更新世 Late Pleistocene	低位段丘2堆積物 Lower terrace 2 deposits	L_2	礫及び砂 Gravel and sand
	低位段丘1堆積物 Lower terrace 1 deposits	L_1	礫及び砂，部分的にシルト，姶良Tn火山灰(21,000-25,000y.B.P.)を挟む Gravel and sand, partly silt, intercalated with Aira-Tn ash (21,000-25,000y.B.P.)
	中位段丘2堆積物 Middle terrace 2 deposits	M_2	礫及び砂，部分的にシルト Gravel and sand, partly silt
	中位段丘1堆積物 Middle terrace 1 deposits	M_1	礫，砂及びシルト Gravel, sand and silt
中期更新世後期 Late Middle Pleistocene	高位段丘堆積物 Higher terrace deposits	H	礫及び砂，部分的にシルト Gravel and sand, partly silt
鮮新世－中期更新世前期 Pliocene to Early Middle Pleistocene	郡中層 Gunchu Formation	Gu	礫，砂及びシルト，火山灰，亜炭層を挟む Gravel, sand and silt, intercalated with volcanic ash and peat
	八倉層 Yakura Formation	Yk	礫及び砂，部分的にシルト Gravel and sand, partly silt
	鳥ノ子層 Torinoko Formation	Tr	礫及び砂，部分的にシルト Gravel and sand, partly silt
	岡村層及びその相当層 Okamura Formation and its equivalents	Ok	礫，砂及びシルト，火山灰を挟む Gravel, sand and silt, intercalated with volcanic ash
	土柱層及びその相当層 Dochu Formation and its equivalents	Dc	礫，砂及びシルト，火山灰を挟む Gravel, sand and silt, intercalated with volcanic ash
	岩屑流堆積物 Debris flow deposits		岩塊及び礫 Rock block and gravel
中期中新世 Middle Miocene	石鎚層群及び貫入岩類 Ishizuchi Group and Intrusive rocks	An	安山岩類 Andesites
始新世 Eocene	久万層群 Kuma Group	Ku	角礫岩 Breccia
後期白亜紀 Late Cretaceous	和泉層群 Izumi Group	Iz	礫岩，砂岩及び泥岩 Conglomerate, sandstone and mudstone
前期－後期白亜紀 Early to Late Cretaceous	三波川変成岩類 Sambagawa metamorphic rocks	Sb	結晶片岩類 Crystalline schists

地すべり地形
Landslide configuration

- 開析されていない，あるいはほとんど開析されていない滑落崖 Main or lateral scarp of which crown is fresh or not dissected
- やや開析された滑落崖 Main or lateral scarp of which crown is partially dissected
- LS_1 滑落崖を伴い，輪郭が明瞭な移動体 Landslide mass with definite margins and main scarp
- LS_2 移動体が残っていない可能性のある地すべり地形 Landform morphology suggestive of a highly eroded landslide
- LS_3 緩慢な滑りあるいはクリープが最近生じた斜面 Unstable slope or incipient landslide mass
- LS_4 滑落崖が不明な移動体または断層運動に伴って分離した岩体 Landslide mass of which main scarp can not be identified or dislodged fault block
- 破線は境界の不明瞭な部分 Broken line shows questionable part of margin

- 活断層（後期更新世－完新世に活動的） Active fault (active during Late Pleistocene to Holocene
- 推定活断層 Inferred active fault
- 伏在活断層 Concealed active fault
- 古期第四系を変位させるが変位地形の不明瞭な断層 Fault which cut older Quaternary deposits but has weak
- 狭義の中央構造線（和泉層群と三波川帯の境界） Median Tectonic Line in a narrow sense as the boundary
- 断層の落下側 Downthrown side of fault
- 断層の横ずれセンス（右ずれ） Strike-slip sense of fault (right-lateral)
- 強い断層破砕帯 Fault fracture zone
- 押しかぶせ断層または断層活動に関連した地すべりの面 Plane of overthrust or landslide related to fault moveme
- 撓曲崖 Flexure scarp
- 10m 低断層崖の比高 Relative height of fault scarplet
- 50m 河川の屈曲とその変位量 Offset stream and its amount
- 段丘面の傾動 Direction of tilted terrace surface
- 背斜軸 Anticlinal axis
- 向斜軸 Synclinal axis
- 膨らみまたは圧縮尾根 Mound or pressure ridge
- 断層鞍部 Fault saddle
- 風隙 Wind gap
- トレンチ掘削地点 Location of trench excavation survey
- 断層露頭 Fault exposure
- その他の露頭及び試料採取地点 Other exposure or sampling location
- Fig. 5 Fig. 18 説明書に説明されている露頭，地域の範囲と図の番号 Extent and figure number of outcrop and area describe
- 崖地形（同一区分の段丘面間にみられる段丘崖） Scarplet (terrace scarp)
- ボーリング地点 Boring site
- 60 断層面の走向及び傾斜 Strike and dip of fault plane
- 20 地層の走向及び傾斜 Strike and dip of strata
- 80 逆転層の走向及び傾斜 Strike and dip of overturned strata
- 植物化石の産出 Occurrence of plant fossil



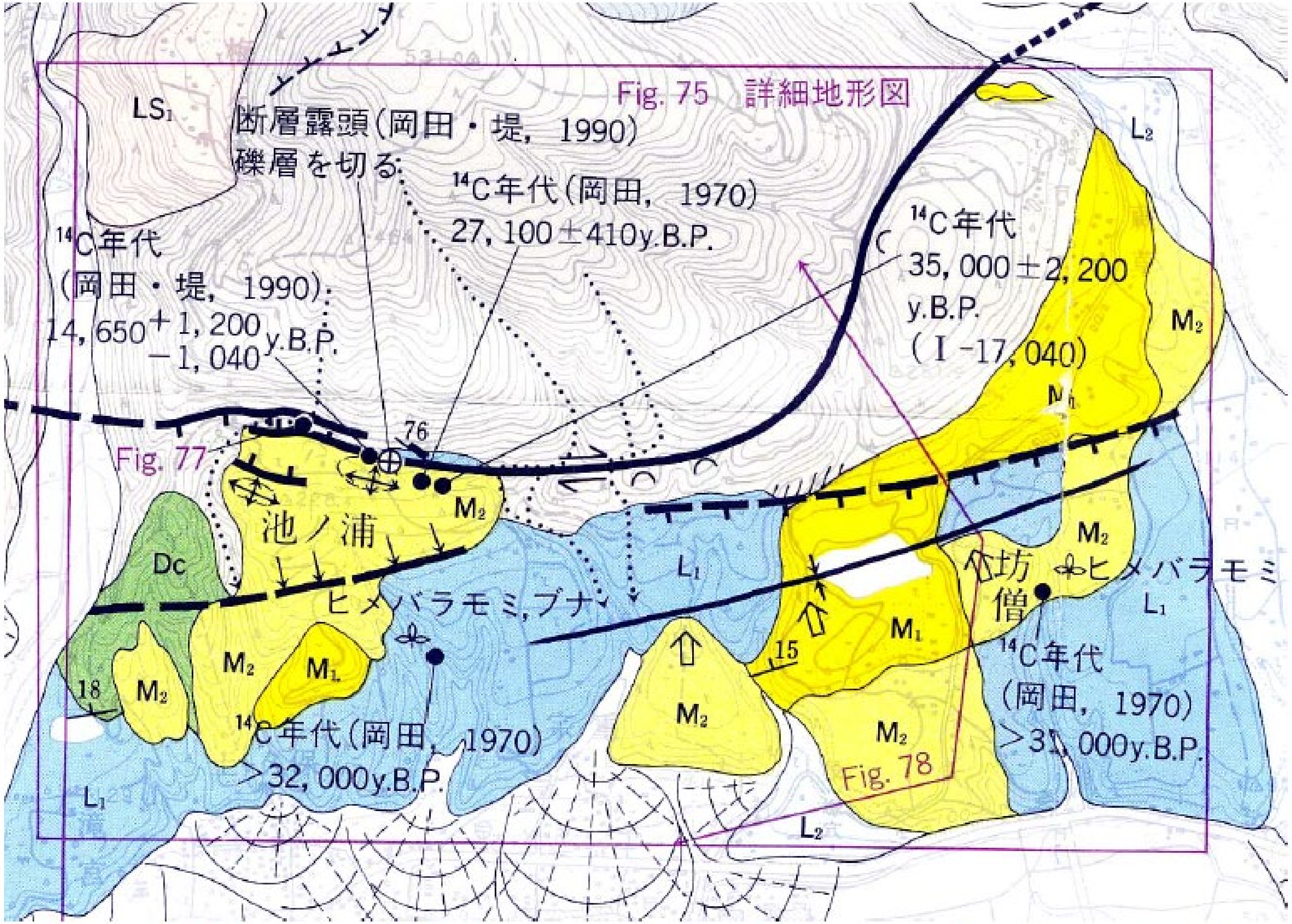
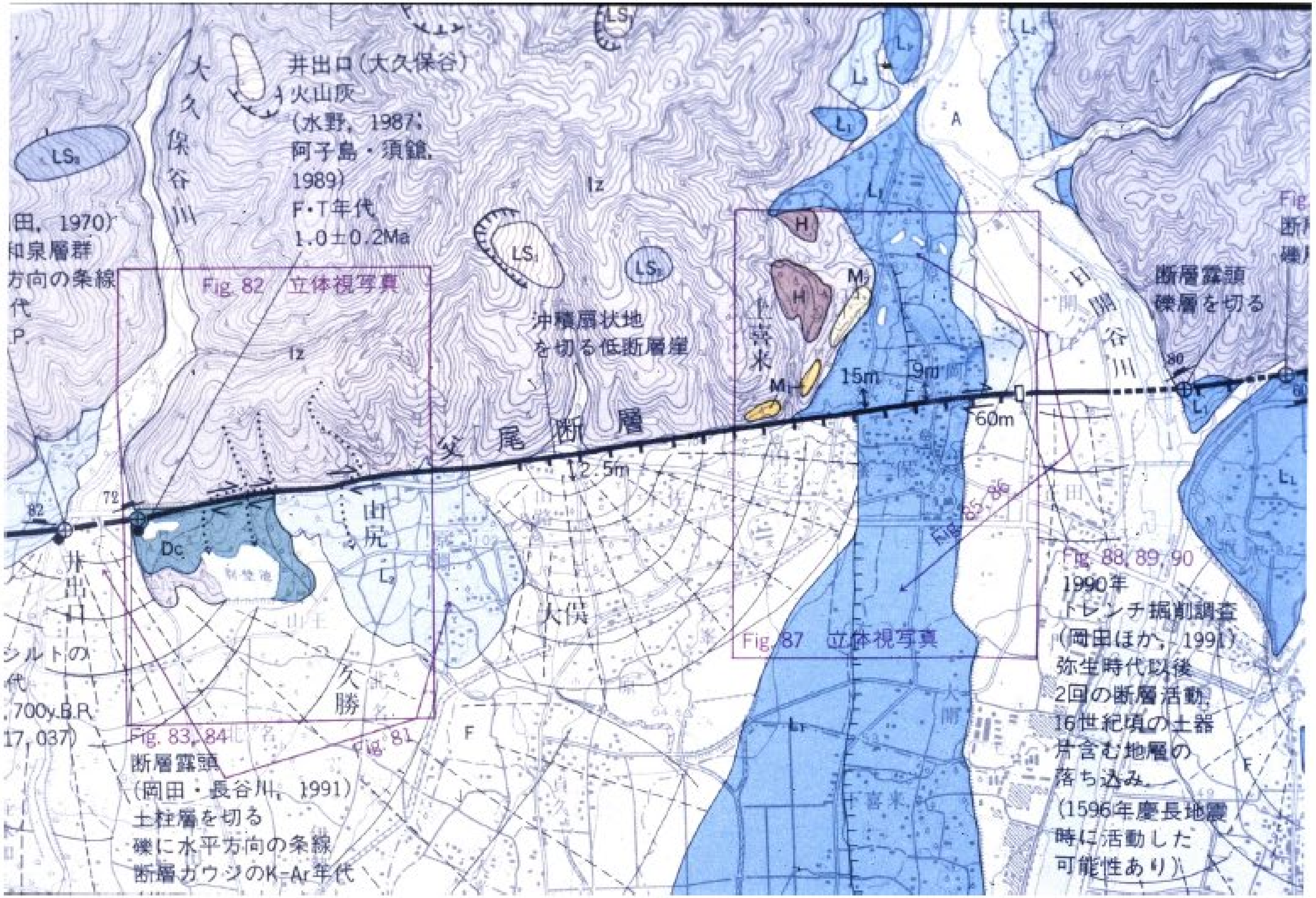


Fig. 4-2 Part of fault strip map (Mizuno and others, 1993), showing the location of trench site at Ikenoura, Mima City, along the Mino fault. Synclinal axis and monoclinal scarp are also described on this map.

Japanese active fault map (from Okada and Ooi field trip guide, 2006)

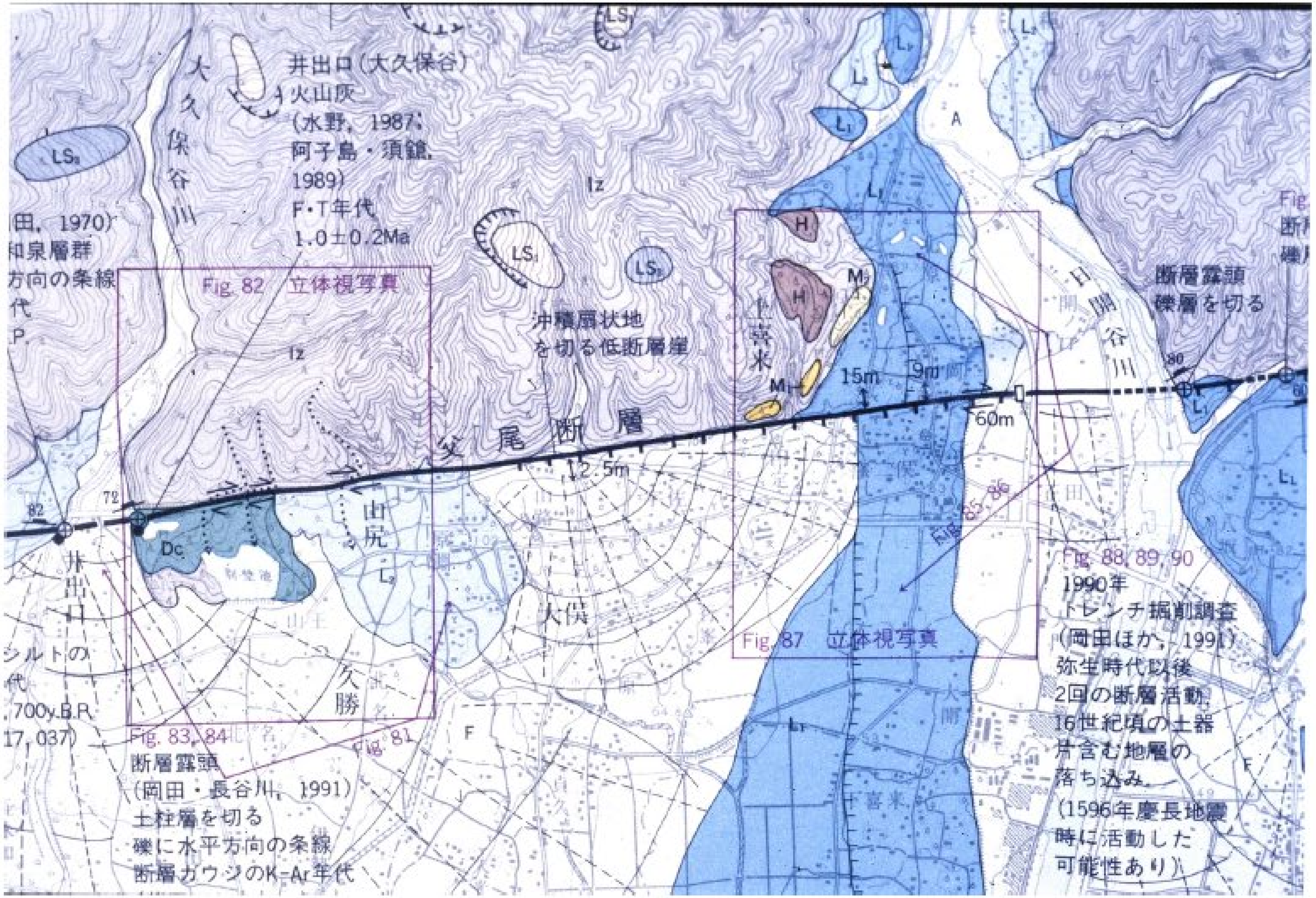


Japanese active fault map (from Okada and Ooi field trip guide, 2006)

Fig. 5-2 Part of fault strip map (Mizuno and others, 1993), showing the location of Ideguchi to Kamigirai, Ichiba Town, Awa City, along the Chichio fault.

Japanese active fault map overview for prior slide (from Okada and Ooi field trip guide, 2006)

Fig.5-3 Oblique aerial photograph of fault scarp and fault outcrop along the Chichio fault, Awa City. View is to the northeast. Photo taken by A.Okada.



Japanese active fault map (from Okada and Ooi field trip guide, 2006)

Fig. 5-2 Part of fault strip map (Mizuno and others, 1993), showing the location of Ideguchi to Kamigirai, Ichiba Town, Awa City, along the Chichio fault.

Japanese active fault map stereopair for prior slide (from Okada and Ooi field trip guide, 2006)

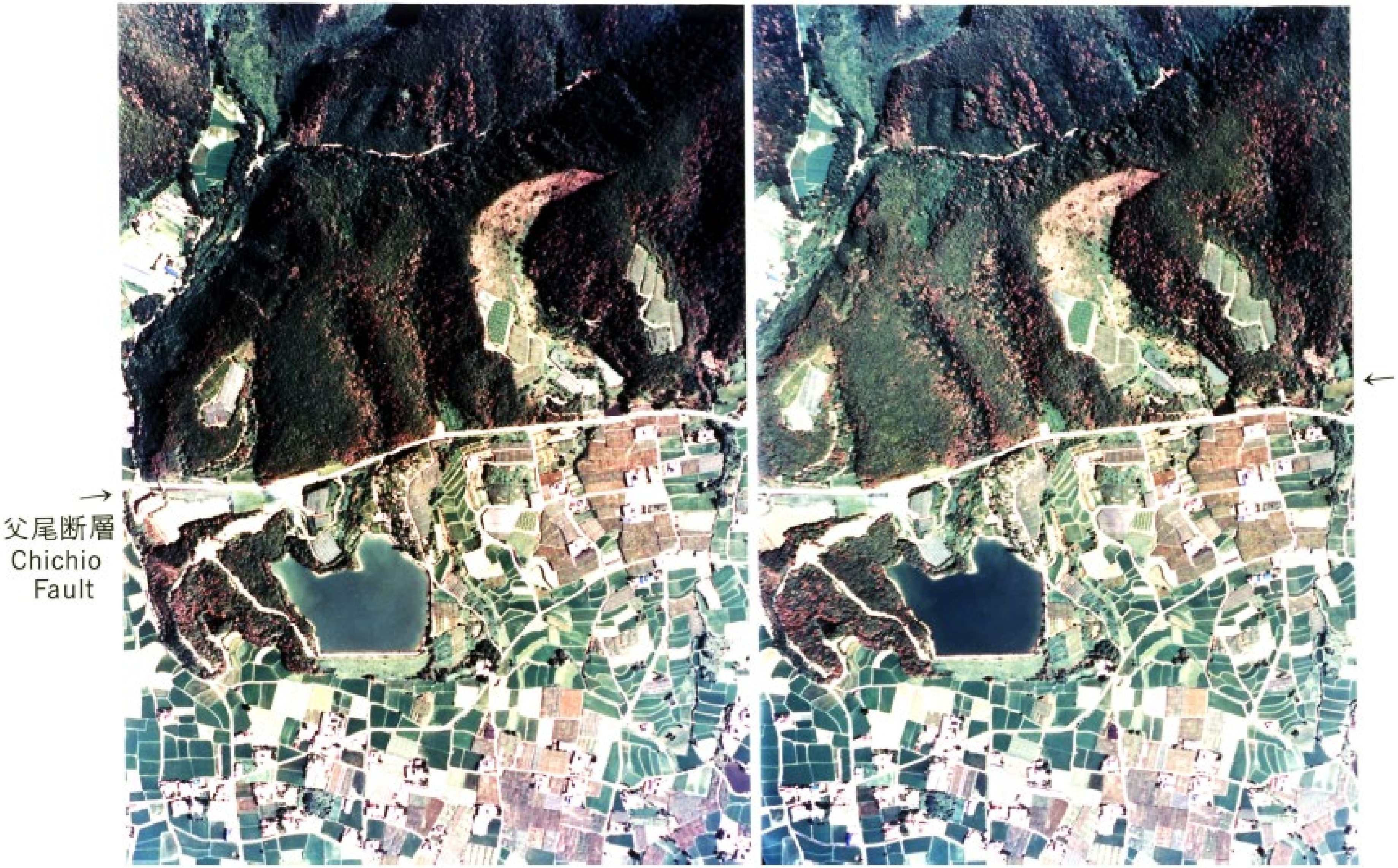
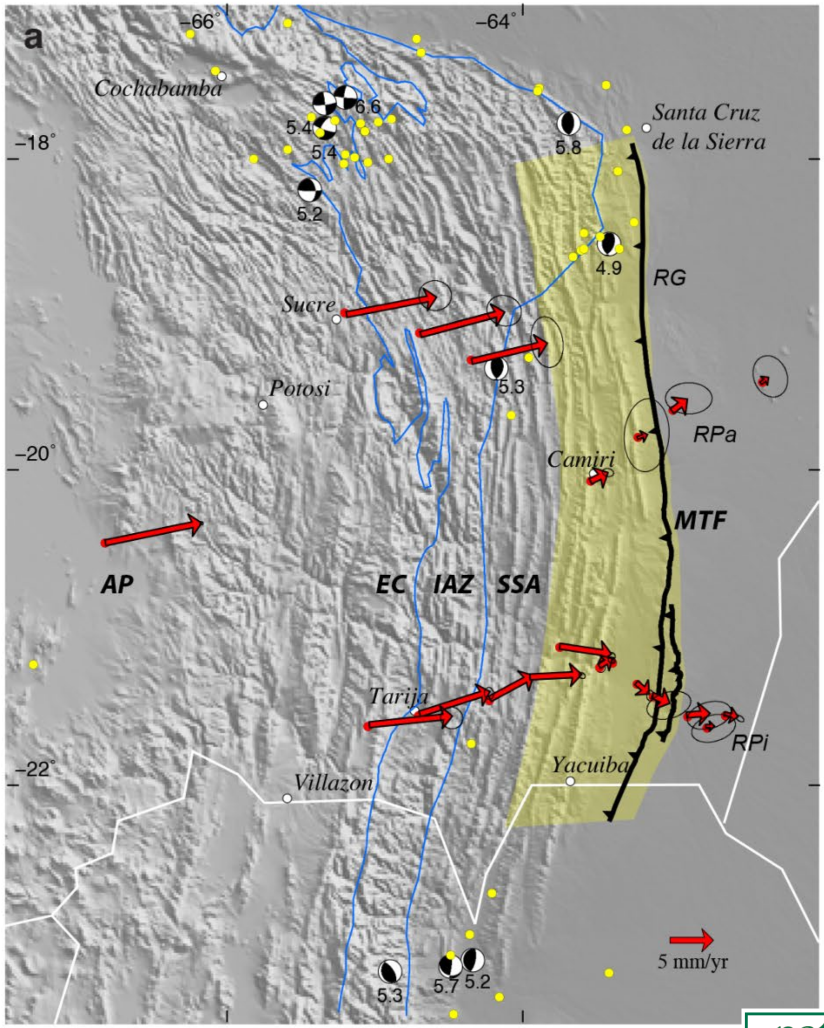
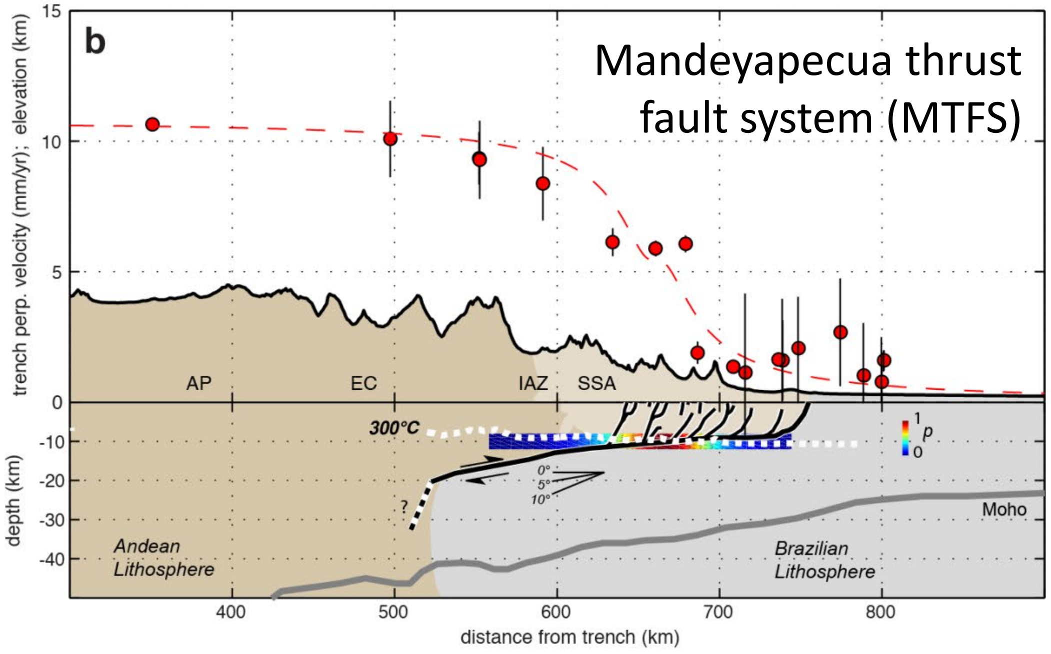
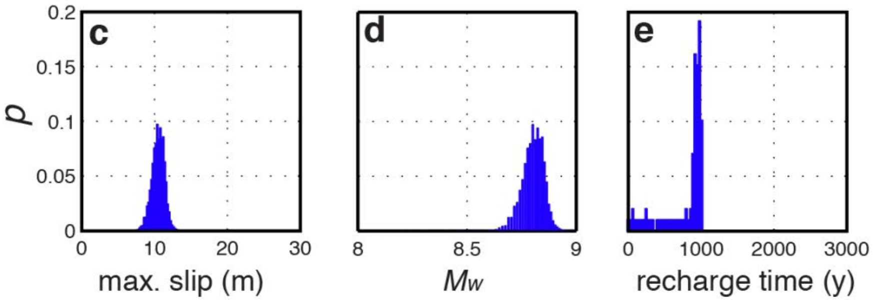


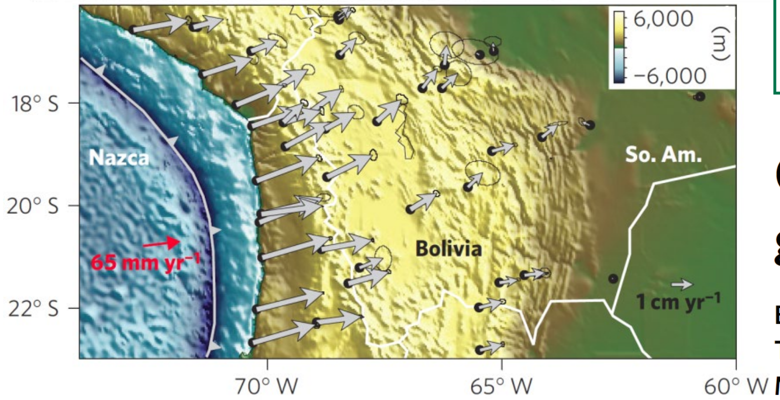
Fig.5-4 Right-laterally offset streams and fault notches at Ideguchi, Awa City, Tokushima Prefecture. Stereo-pair of aerial photographs by Geographical Survey Institute.

Heuristics by demonstration: examples of fault maps: Bolivia eastern Andean foreland thrust fault









nature geoscience

LETTERS

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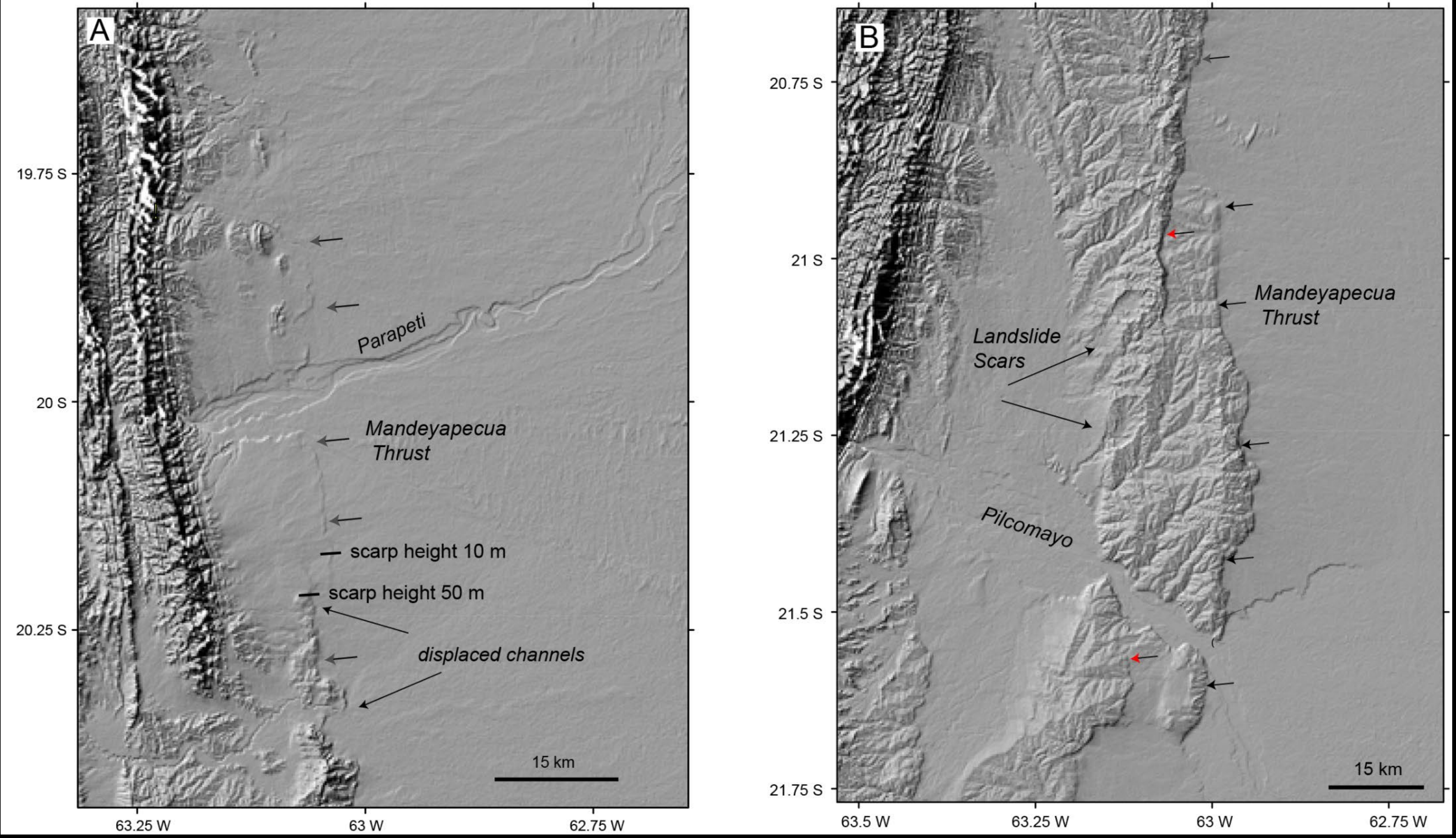
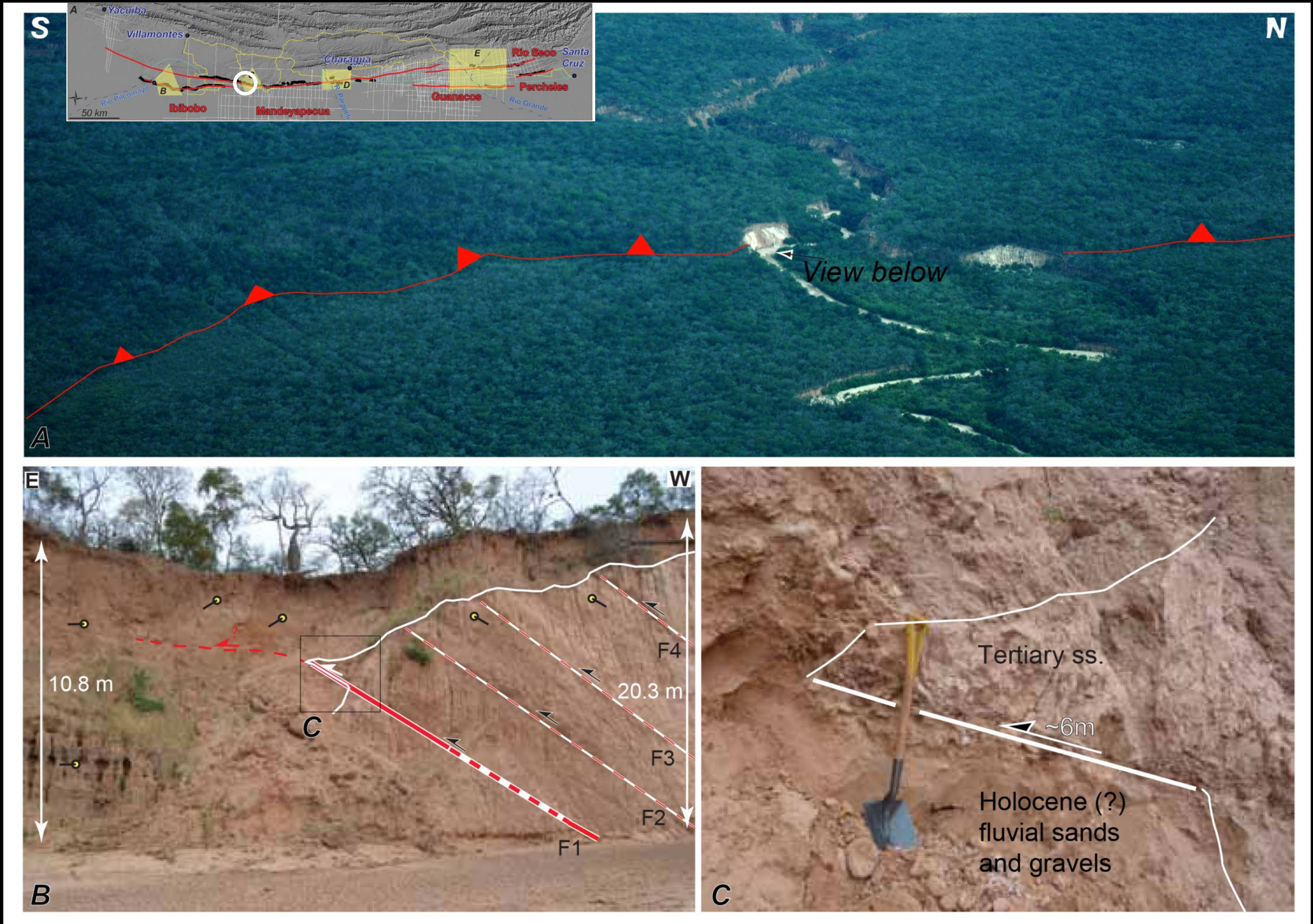
Orogenic-wedge deformation and potential for great earthquakes in the central Andean backarc

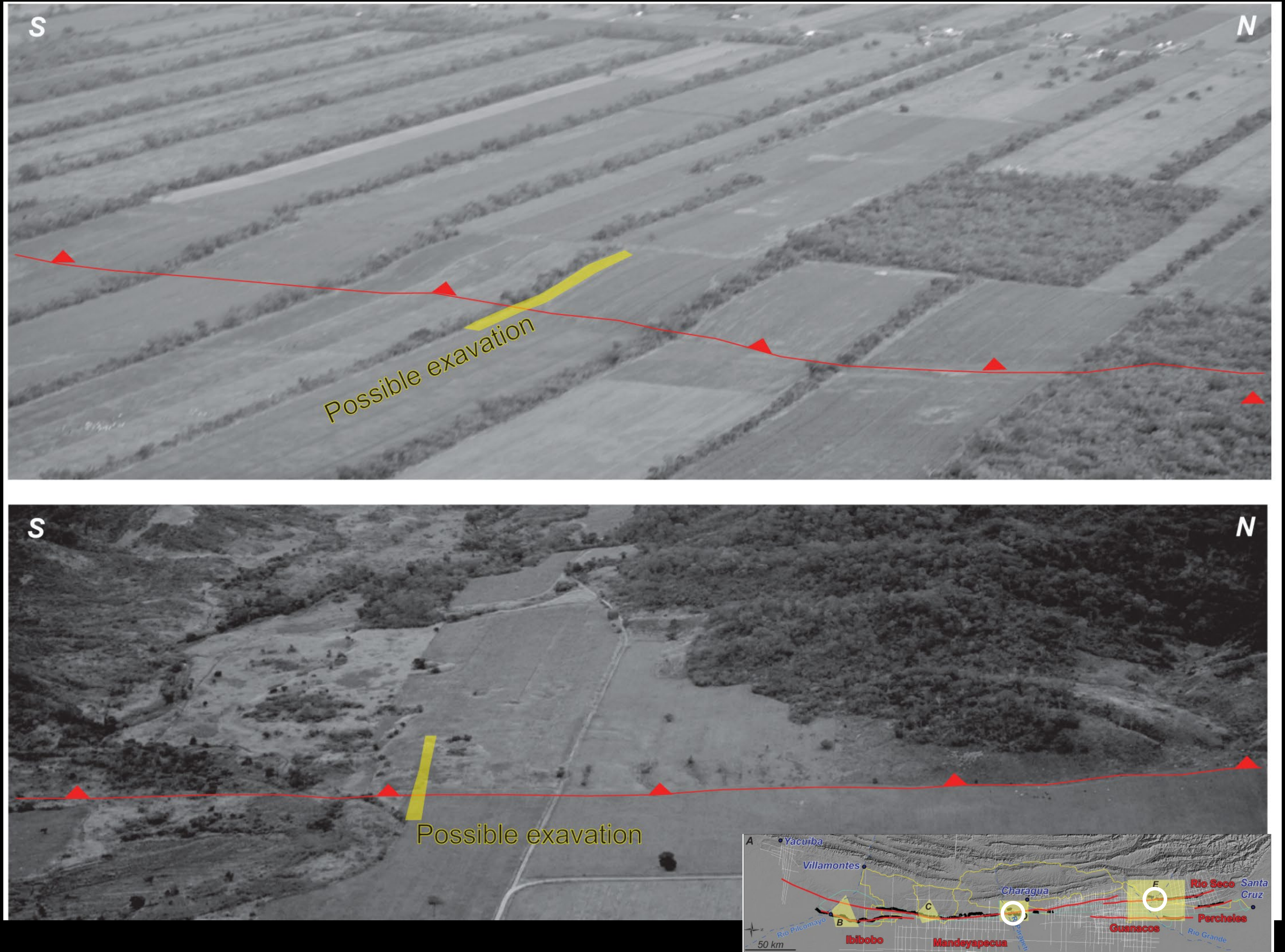
Benjamin A. Brooks[1]*, Michael Bevis[2], Kelin Whipple[3], J Ramon Arrowsmith[3], James Foster[1], Tomas Zapata[4], Eric Kendrick[2], Estella Minaya[5], Arturo Echalar[6], Mauro Blanco[7], Pablo Euillades[7], Mario Sandoval[6] and Robert J. Smalley Jr[8]



Big fault scarps in SRTM 90 m DEM!



S
N
A
Yacuiba
Villamontes
Charagua
Rio Seco
Santa Cruz
E
D
B
Percheles
Guanacos
Rio Grande
Rio Pilcomayo
Ibibobo
Mandeyapecua
50 km
View below
E
W
10.8 m
20.3 m
F4
F3
F2
F1
C
B
Tertiary ss.
~6m
Holocene (?) fluvial sands and gravels
C


S
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Possible exavation
S
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Possible exavation
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Yacuiba
Villamontes
Charagua
Rio Seco
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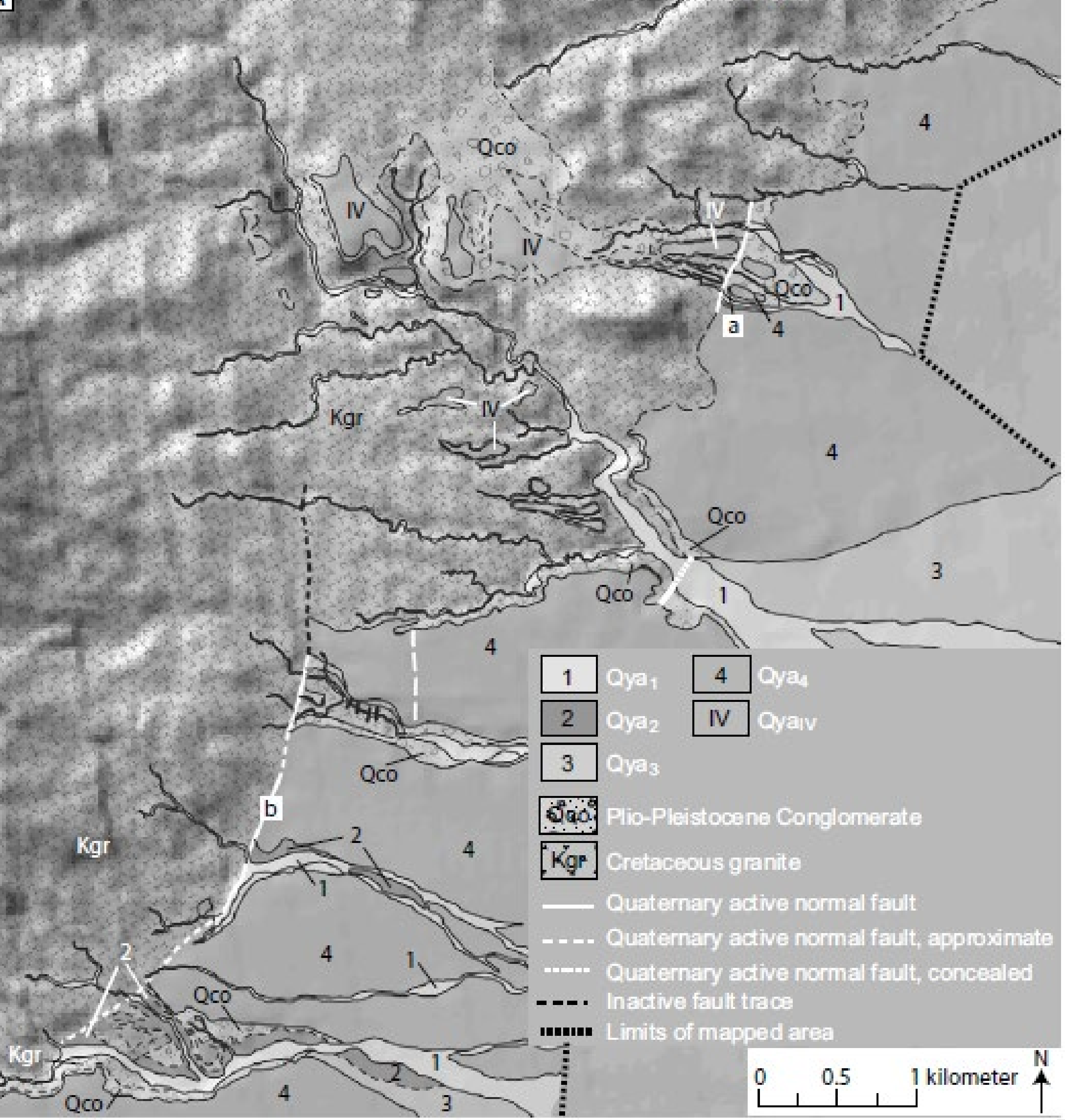
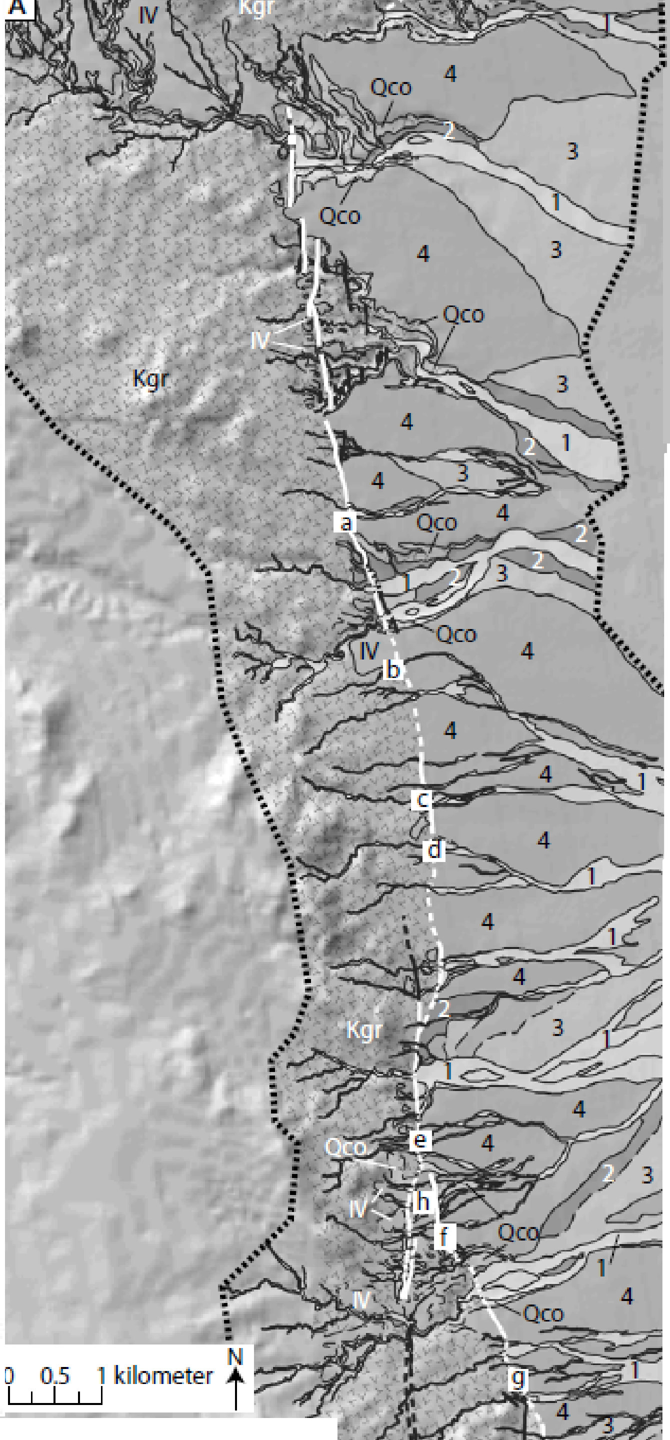
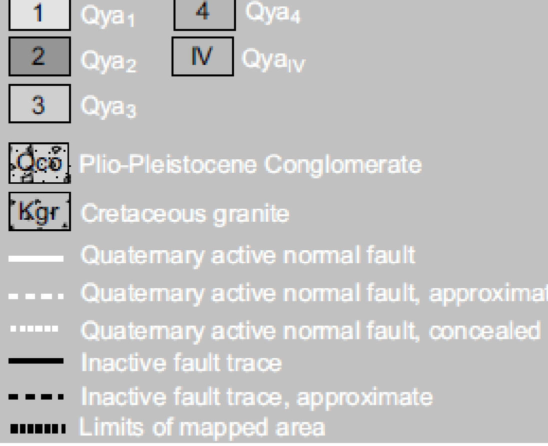
Cruz
Percheles
Guanacos
Ibibobo
Mandeyapecua
Rio Pilcomayo
Rio Grande
B
C
E
50 km

Heuristics by demonstration: examples of fault maps: Baja California normal fault scarps



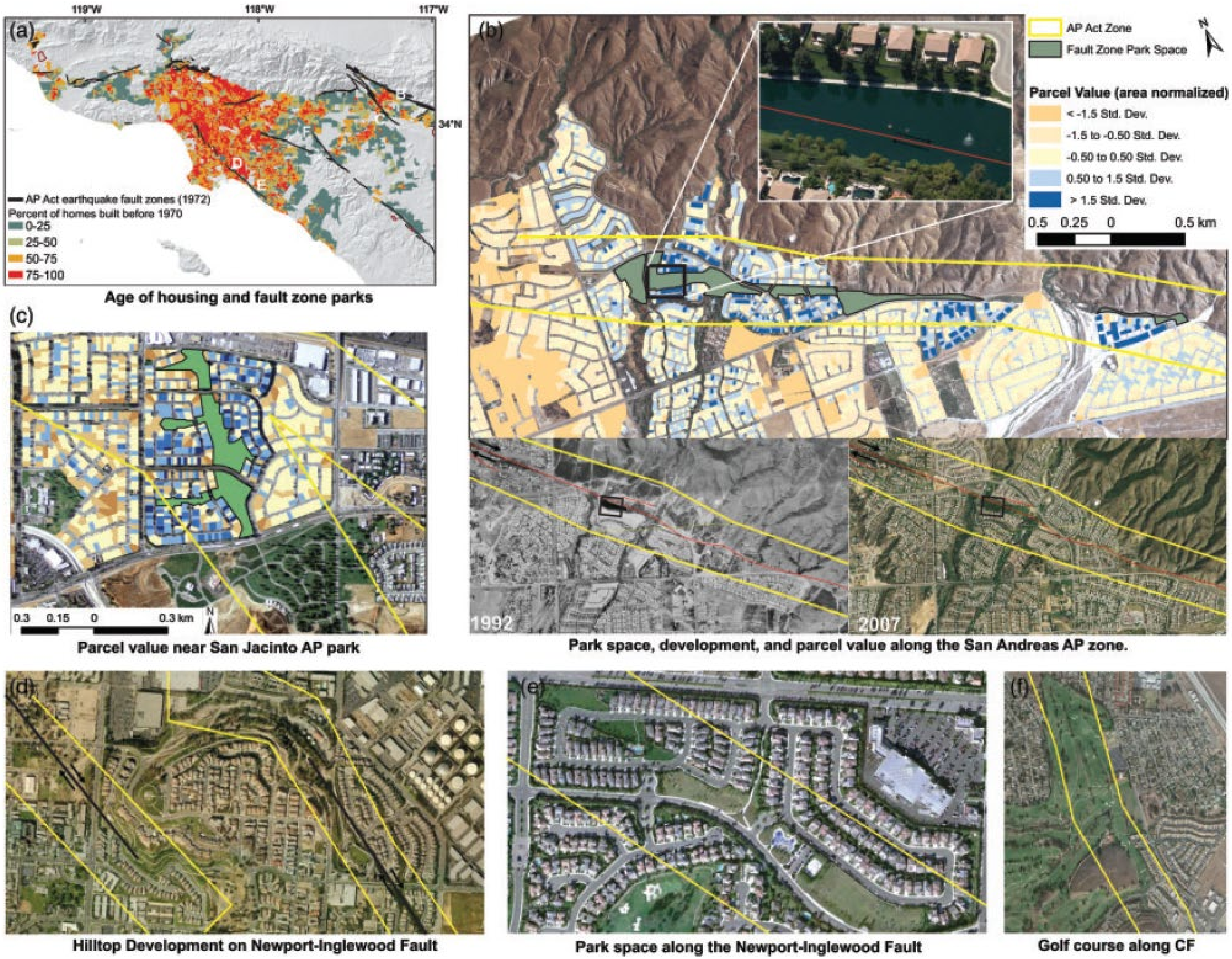




Busch, M., Arrowsmith J R., Umhoefe P., Coyan, J., Kent, G., Driscoll, N., Martinez Gutierrez, G., Geometry, segmentation, and Quaternary slip behavior of the San Juan de los Plane and Saltito fault zones, Baja California Sur, Mexico: Characterization of rift-margin normal faults, Geosphere, v. 9 p. 426-443, doi:10.1130/GES00806.1, 2013.

Unexpected consequences of fault zone delineation and regulation

Toke, N. A., Boone, C. G., Arrowsmith, J R., Fault Zone Regulation, Seismic Hazard, and Social Vulnerability in Los Angeles, California: Hazard or Urban Amenity? Earth's Future, Volume 2, Issue 9, Pages: 440-457, DOI: 10.1002/2014EF000241, 2014.



Mapping and image interpretation

Basic considerations for interpretation

- Shape: general form, configuration, outline of individual objects.
- Size: consider in context of image scale
- Pattern: spatial arrangement of objects (e.g., orchard)
- Tone: relative brightness or color of objects on an image
- Texture: frequency of tonal change (smoothness or coarseness)
- Shadows: gives profile view of object and implies relative heights
- Site: refers to geographic or topographic location; what do you expect to be there?
- Association: occurrence of certain features in relation to others
- Resolution: what is the finest thing you can see?
- Targets: identify main features you want to emphasize on your map

Mapping

- Geomorphic mapping
  - Important means of establishing landforms, their distributions and relations to each other, process distributions, and history
- Quaternary geologic mapping
  - Emphasis on young deposits and landforms that are usually lumped into one unit in bedrock mapping. Uses both the deposit characteristics as well as the landform shape and position in the landscape as criteria for unit designation.

I cannot work on anything unless I map it first!

Ramón's Mapping Mantras

1. Scale: If your pencil is 0.5 mm in diameter, how big on the ground is it if you are mapping on a 1:24,000 scale map? How about on a 1:500,000 map?
2. Even coverage: if there is blank space, you did not look there.
3. Strive to provide detail. Do not generalize.

Ramón's Mapping Mantras

4. All lines mean something.
5. Consistent notation and symbology.
6. Quality control. Use dashing, variable line weights, queries. If something is uncertain or approximate, indicate so.
7. Data/ink ratio-> 1. Put emphasis on important things (data) by putting relatively more ink in them—greater line weights, larger text., etc.
8. Neatness counts.

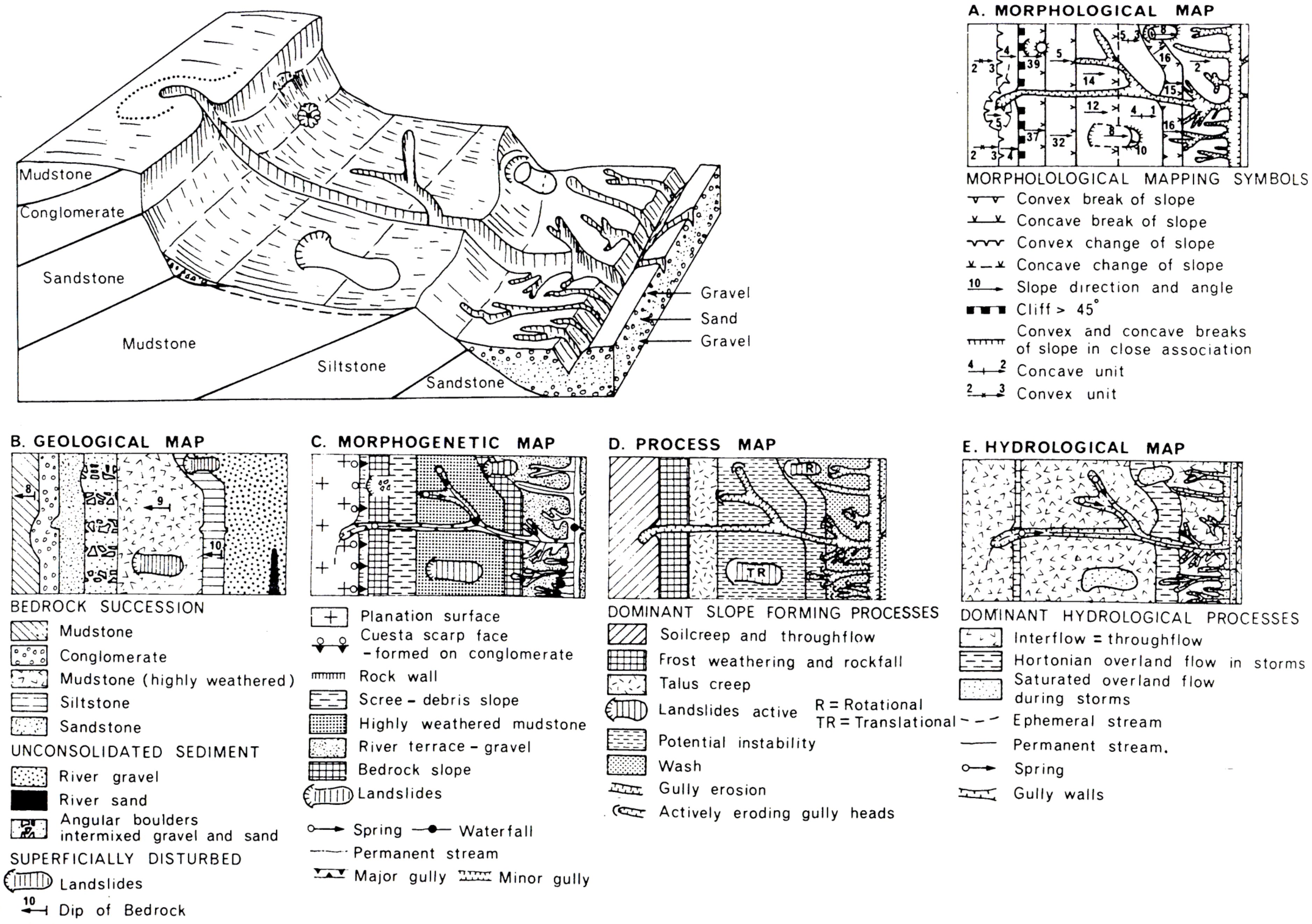


FIG. 10.3. Maps are some of the most common landscape models. These maps show various features and interpretations of one landscape represented in a block diagram. Such maps are very useful for recording field observations. (Modified and extended from Brunsden *et al.* 1975.)