Dynamics of fault slip at the interface of the Garlock fault with the Walker Lane belt, Spangler Hills, California

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Abstract

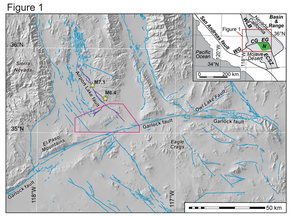
The sinistral Garlock fault zone is a wide region of active deformation that accommodates transversely oriented dextral slip of the Walker Lane belt. The 2019 Ridgecrest earthquakes ruptured mostly unstudied faults within the zone of interaction. We present geologic mapping and fieldwork data of offset markers for numerous faults to examine the slip history and to interpret the mechanisms of accommodation of dextral slip into the Garlock fault.

We evaluated the total offset on the Airport Lake fault (ALF) in the Spangler Hills using Jurassic and Pliocene rocks and Pleistocene sediments. The splays of the NW-striking ALF have dextral slip of 200, 100, 150, and 600 m, going from east to west. The eastern splays have fault scarps related to the 2019 earthquakes. These splays can be followed southward to the Garlock fault, where they offset NW-dipping Pliocene rocks. The trace of the ALF across a wide valley of intervening alluvium coincides with a northward deflection of Pleistocene lake high-stand shorelines indicating uplift of the east side of the ALF. The calculated offset of the Pliocene rocks is comparable to the offset of Jurassic rocks in the Spangler Hills.

A SW-striking zone of sinistral slip occurs north of the Spangler Hills and west of the ALF. These faults have larger measured amounts of total offset of Jurassic features than the ALF, of 500 to 700 m each, for a total of >3000 m. These also cut Pliocene to Pleistocene sediments and the northern ones have fault scarps from the 2019 earthquakes. The older, inactive sinistral strands are offset by northwest striking dextral faults.

The interpreted history shows an eastward progression of dextral faulting. There is a northward migration of activity on the sinistral faults with the older segments being offset by the older dextral faults. This progression indicates that the sinistral faults are the dominant component of accommodation of the incoming dextral slip and should be reexamined for seismic hazards analysis.

Figure 1



Introduction

WLB-ECSZ dextral faulin eastern California
Garlock not cut by these, both active. How accommodate the dextral slip without cutting through the transversely oriented, sinistral slip Garlock fault?

Paired set of sinistral and dextral fault scarps from 2019 M6.4 & M7.1 earthquakes in the Spangler Hills

We test accommodation models (Andrew et al., 2014) by examining total slip on the dextral AirportLake fault system and the sinsitral Spangler Hills fault zone.

New geologic mapping from area only known via reconaisance geologic data.

Cerro Coso fault (dextral slip, SSE-strike)

-Cuts units as young as Pleistocene(?)
-Expressed topographically
-Unknown interaction with sinistral faults
-Previous estimates of 7000-9000 m of slip
  - (Casey et al., 2008; Andrew and Walker, 2019 & 2020)
  -based on offset north-striking dextral mylonitic shear zones in Jurassic plutonic rocks
-New slip estimates are much smaller
  -More than one of these dextral shear zones have been found
  -plutonic rocks can't be matched with the large offset value.
  -similar plutonic rocks and dike assemblages occur on both sides of the fault in its central exposures.
  -Poor exposures limit the maximum slip to be 1200 m on eastern splay
  -A western splay has a better constrained offset of the plutonic rocks and dextral shear zone of ~1000 m.

Mapped Geologic Units

Quaternary
Christmas Canyon Fm. conglomerate

Pliocene
exotic clast conglomerate
arkosic sandstone
felsic tuff
arskosic sandstone of mb. 2 of fm. of Pilot Knob Valley
conglomerate of mb. 1 of fm. of Pilot Knob Valley

Miocene(?)
channel exotic boulder fill

Jurassic
porphyry of Spangler Hills
granodiorite of Poison Canyon
granodiorite of Wagon Wheel
alaskite of The Pinnacles
quartz diorite of Stephens Holdings
-associated aplitic to microgranitic sills
quartz monzonite of Rademacher Hills
quartz monzodiorite of Laurel Mountain
quartz diorite of Ridgecrest

Spangler Hills fault zone (sinistral slip, ENE-strike)
(Salt Wells Valley fault zone of Thompson-Jobe et al. (2020))

Northern splays
-Fault scarps from 2019 earthquakes
-Expressed topographically
-Coseismic with the eastern splays of the NW-striking Airport Lake fault zone
  -this may cut the western splays of the Airport Lake fault zone, but poor exposures
-Few well constrained sinistral slip (from north to south)
  - 300 to 1000 m of offset of quartz diorite containing mafic dikes (poorly constrained)
  - >2000 m fine-grained monzogranite within quartz diorite490 m offset NNW-striking ductile shear zone
  - 18 m offset of aplite dike in granodiorite with fresh cracks and fault scarps
  - 490 m offset of ductile shear zone with monzogranite & quartz diorite package
  TOTAL = 3300 to 4000 m of offset

Central splays
-no known 2019 fault scarps
-cuts light-colored arkosic sandstone, interpreted to be older weathering surface of the Spangler Hills before uplift and dissection
-cut by NNW-striking dextral faults
-Multiple offset constraints (from north to south)
  - 2600 m offset of northerly-striking dextral shear zones
  - 540 m offset distinctive composition and geometry mafic dikes
  - 450 m offset distinctive composition and geometry mafic dikes
  - 700 m offset distinctive composition and geometry mafic dikes
  - 290 m offset of western contact of a fine-grained monzogranite body in quartz diorite
  - 1600 m offset of western contact of a fine-grained monzogranite body in quartz diorite
  This main offset sinistral fault appears to continue east where it is dextral offset by several faults (see discussion with the Airport Lake fault)
  TOTAL = 4500(?) m of offset

Southern splays
-no known 2019 fault scarps
-cuts light-colored arkosic sandstone, interpreted to be older weathering surface of the Spangler Hills before uplift and dissection
-appears to cut southern end of the Cerro Coso fault
-cut by all splays of the NW-striking dextral Airport Lake fault
-numerous possible related fault splays in Teagle Wash to the east
-Poorly constrained offset (from north to south)
  - poorly constrained ~1000 m offset of deposits of Pliocene(?)(tuff
  - poorly constreained ~1100 m offset of volcanic clast conglomerate
  - more splays exposed to east with unknown horizontal offset
  TOTAL = ~2000 m

Airport Lake fault zone (dextral slip, SSE-strike)
(Paxton Ranch fault zone of Thompson-Jobe et al. (2020))

western splay
-Cuts units as young as Pliocene(?)
-Cuts central sinistral faults
  -Key relationship with southernmost fault of the central Spangler Hills fault zone is covered by alluvium
-This dextral fault appears to cut the sinistral fault
-just south of this intersection is a well exposed low-angle fault with dextral, low-rake slip
-this fault somehow takes up the slip from the well-exposed western dextral splay fault, as seen to the north of the intersection.

West-central splay
-Cuts units as young as Pliocene(?)
-Cuts southern sinistral faults
-Joins east-central fault to south:
-Dextral slip is poorly constrained, several possible matches from:
  - 18 m offset of a NE-striking mafic dike
  - 120 m offset of NE-striking fault
  - 180 m offset of a sheared and partially foliated granodiorite dike
Favored interpretation
-Similar offset possible of the southernmost fault of the central Spangler Hills fault zone

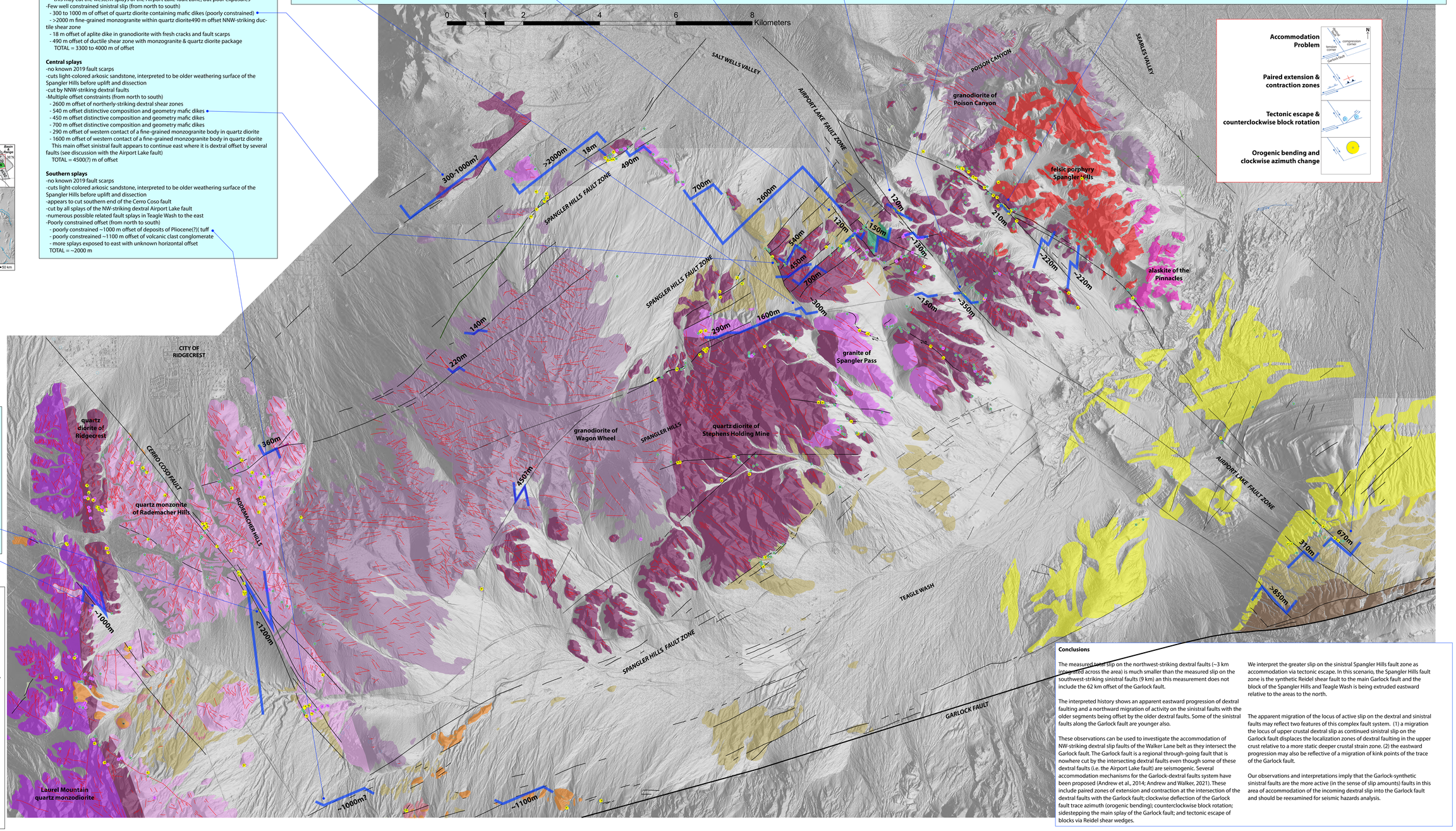
Central splay
-Cuts units as young as Pliocene(?)
-Cuts central and southern sinistral faults
-Poorly exposed
-Joins east-central fault to south:
-Offsets Pliocene exotic boulder deposit
  -~150 m offset of a paleovalley edge with exotic boulder clast fill
-similar amount of slip probable for offset of a few m wide WSW-striking shear zone

East-central splay
-Fault scarps from 2019 earthquakes
-Joins eastern splay northward
-Not strongly expressed topographically
-Small offset
  -120 m offset of NW-striking wide mafic dike, unique composition and texture, no projection
-similar offset WSW-striking ductile shear zone

-Follow to the south across Teagle Wash
  - Apparent maximum slip of >850 m offset of contact of dark clast conglomerate under pebbly sandstone
-Appears to offset the southernmost fault of the central Spangler Hills fault zone
- ~350 m offset but poor exposures and includes the slip merged from the central splay of the Airport Lake fault

Eastern splay
-Fault scarps from 2019 earthquakes
-Not strongly expressed topographically
-Small offset
  - 210 m offset of unique epidote altered mafic dike exposed on both sides of fault scarp
  - similar amount of slip possible on several distinctive NE-striking felsic hypabyssal dikes, much less precise because of relatively large projection amounts across alluvial valley

-Fault scarps and fault-line scarps can be followed southeast to near the Garlock fault
  - cut Pliocene (>3.6 Ma) sedimentary rocks
  - continue all the way to end at a splay of the Garlock fault
  - offset gently to moderately (15-25 degrees) north-dipping Pliocene rocks (east to west)
  - Apparent 670 m offset of contact of pebbly sandstone under siltstone
  - Apparent 310 m offset of contact of pebbly sandstone under siltstone
  - These faults have east side up relative slip based the deflection of Pleistocene shorelines and the offset markers are gently dipping northward.



Conclusions

The measured total slip on the northwest-striking dextral faults (~3 km integrated across the area) is much smaller than the measured slip on the southwest-striking sinistral faults (9 km) an this measurement does not include the 62 km offset of the Garlock fault.

The interpreted history shows an apparent eastward progression of dextral faulting and a northward migration of activity on the sinistral faults with the older segments being offset by the older dextral faults. Some of the sinistral faults along the Garlock fault are younger also.

These observations can be used to investigate the accommodation of NW-striking dextral slip faults of the Walker Lane belt as they intersect the Garlock fault. The Garlock fault is a regional through-going fault that is nowhere cut by the intersecting dextral faults even though some of these dextral faults (i.e. the Airport Lake fault) are seismogenic. Several accommodation mechanisms for the Garlock-dextral faults system have been proposed (Andrew et al., 2014; Andrew and Walker, 2021). These include paired zones of extension and contraction at the intersection of the dextral faults with the Garlock fault; clockwise deflection of the Garlock fault trace azimuth (orogenic bending); counterclockwise block rotation; sidestepping the main splay of the Garlock fault; and tectonic escape of blocks via Reidel shear wedges.

We interpret the greater slip on the sinistral Spangler Hills fault zone as accommodation via tectonic escape. In this scenario, the Spangler Hills fault zone is the synthetic Reidel shear fault to the main Garlock fault and the block of the Spangler Hills and Teagle Wash is being extruded eastward relative to the areas to the north.

The apparent migration of the locus of active slip on the dextral and sinistral faults may reflect two features of this complex fault system. (1) a migration the locus of upper crustal dextral slip as continued sinistral slip on the Garlock fault displaces the localization zones of dextral faulting in the upper crust relative to a more static deeper crustal strain zone. (2) the eastward progression may also be reflective of a migration of kink points of the trace of the Garlock fault.

Our observations and interpretations imply that the Garlock-synthetic sinistral faults are the more active (in the sense of slip amounts) faults in this area of accommodation of the incoming dextral slip into the Garlock fault and should be reexamined for seismic hazards analysis.