Stream Channel Offset and Abandonment and a 200-year Average Recurrence Interval of Earthquakes on the San Andreas Fault at Phelan Creeks, Carrizo Plain, California

John D. Sims, U.S. Geological Survey, National Center 905, Reston VA 22092

The Carrizo Plain segment of the San Andreas fault is noteworthy as an area that clearly displays offset, diverted, and abandoned channels. The channels result from the interaction of strike-slip fault processes, and the geomorphic processes of erosion, transport, and deposition. This interaction produces periodically abandoned channels accompanied by the incision of new channels across the San Andreas fault. Geomorphic features such as scarps, offset stream channels, grabens, and pressure ridges mark the surface trace of the fault. Excavations reveal offset sedimentary and stratigraphic features, evidence of individual earthquake events, and features related to the process of tectonically-induced stream abandonment. The offset channels consist of three elements; a pair of offset modern streams and two abandoned paleochannel groups: a partly infilled channel of intermediate age (paleochannel H), and a pair of mostly infilled, older abandoned coeval channels (paleochannels L and M). Thalwegs of the modern stream channels are offset 17.4 ± 1.6 m and 15.8 ± 0.6 m respectively. Excavations in the alluvium-filled younger abandoned paleochannel reveal that it is offset 101.9 ± 1.4 m from the smaller and 152 m from the larger of the modern channels.

The model developed here is applied to a pair of intermittant streams with a small to moderate-sized drainage basin in an arid to semiarid climate such as that of Phelan Creek, a site at which the pair of intermittant streams has been recurrently offset throughout most of Holocene time (see figure). This model is a new paradigm for neotectonic investigations seeking detailed paleoseismological histories from alluvial paleochannel deposits. It further demonstrates the usefulness of commonly available fluvial channel deposits in contrast to the rarer but more frequently studied ponded deposits. At the Phelan site, the southern channel, Big Phelan Creek, is larger than the northern stream, Little Phelan Creek. Northward extension of Big Phelan Creek west of the fault eventually results in the capture of the northern channel. Additional discharge contributed by the newly captured channel may aid in rejuvenation of the channel below their confluence and may cause erosion of the older deposits in the channel. Rejuvenation at this stage is largely dependent on storms because the size of the smaller drainage basin is about one-quarter that of the larger basin.

The major control on deposition at Phelan Creeks is lengthening of the stream channel along the fault after each surface rupture event. Fault movement develops a low-slope along-fault segment of the stream. Deposition occurs largely in this segment because of reduced slope and from the reduced stream-flow rate required to turn from the initial fault-normal segment to the along fault segment. The channel again turns sharply at the end of the along-fault segment to the downstream fault-normal fault-normal segment. Deposition begins in the upstream bend area as a response to decreased current velocity as the stream rounds the upstream bend to the along-fault channel segment. Each lengthening episode forces the along-fault segment to readjust to its slope and a new depositional cycle is initiated.

The paleochannel deposits at the Phelan Creeks site span a period of about 7000 years and record depositional responses to channel deformation over that period. The younger paleochannel deposits at Phelan Creeks contain abundant charcoal and record five major earthquakes over the last 1150 years. We also tentatively identify a sixth event. The recurrence interval of the last five earthquakes ranges from about 150 to about 300 years. Surface displacement in each of the last two events was about 7½ meters. Charcoal is less abundant in paleochannel deposits older than about 1,150 years. Thus, we are unable to determine an equally detailed history of recurrent offset of Phelan Creeks by the San Andreas fault for the period from ~1,100 to ~7,000 BP. The effects of earlier recurrent offset of the channels of Little and Big Phelan Creeks is recorded in the two abandoned paleochannel sequences. The modern channels illustrate the effects of recurrent movement along the fault after only two earthquakes. Recurrent offset of Big and Little Phelan Creeks results in lengthening of their along-fault channel-segments. After about 45 m of offset the western reach of Big Phelan Creek captures Little Phelan Creek. The signature of this capture may be seen in the sequence of deposits in the along-fault channel segment.

Four sedimentologically distinct phases of alluviation record the recurrent offset of this abandoned paleochannel. Alluviation within the paleochannel occurred as a response to its increased length and decreased slope along the fault during recurrent offset. Characteristically the vertical component of fault slip is small. We hypothesize that unconformity-bounded sedimentary units represent phases of alluviation associated with increased offset of the stream channels along the fault and thus constrain the times of earthquakes. The older abandoned paleochannel contains three phases of alluviation and two phases of colluvium accumulation, and the younger abandoned paleochannel contains four phases of alluviation. Earlier phases of alluviation represent longer periods of time than later ones because the earlier ones are representative of cut-and-fill conditions so that accumulation was low. Later phases of alluviation in the younger paleochannel represent depositional phases associated with individual earthquakes. Alluvial fill in the older abandoned paleochannels at the northwest end of the study site records their separation from their headwaters by recurrent strike-slip movement on the San Andreas fault over the past 7,000 years. The pair of older abandoned channels is offset 238 m ± 1.5 m from the pair of modern channels. This yields a Holocene slip rate of ~34 mm/yr.

The last six events at Phelan Creeks are dated, in the AD/BC convention at 1857, ~1505, 1361 ± 38, 1236 ± 15, 1003 ± 20, and tentatively 838 ± 35. The 1505 event is not directly dated at Phelan Creeks although physical evidence for it is present. I use the date of the event from the Bidart site 5 km southeast of Phelan Creeks. The 1361 event is dated by the abandonment of paleochannel H and probably postdates the earthquake. The date of event R, 1346 ± 17, at Pallet Creek may be more accurate. The remaining dates for earthquakes at this site derived from multiple radiocarbon dates applied to the interpretation of depositional sequences using the tectono-sedimentological model presented above.

EPHEMERAL CHANNEL RESPONSE TO RECCURENT OFFSET–SCHEMATIC MODEL