LIST OF RECENT EARTHQUAKES THAT POSSIBLY HAD SURFACE RUPTURE; v. 1.0
By Jim McCalpin, 23-SEPT-2016

BACKGROUND

This list was generated by Jim McCalpin in support of the SURFACE Project of INQUA and its contained SURE database (Surface Rupture during Earthquakes). The SURFACE project (SURface FAulting Catalogue – Earthquakes) was initiated in 2016 under the Terrestrial Processes (TERPRO) Commission as project 1620R. Project leaders are F. Audemard (Venezuela), S. Baize (France), F. Cinti (Italy), C. Costa (Argentina), J. McCalpin (USA), A. Michetti (Italy), K. Okumara (Japan), and O. Scotti (France). The project website is:
http://www.earthquakegeology.com/index.php?page=projects&s=4

The SURCE database would update previously published databases that relate earthquake magnitude to surface faulting (both primary and distributed faulting). The existing databases have several weaknesses: (1) they were compiled in the 1990s and 2000s, so do not contain surface faulting descriptions from earthquakes in the past 15-20 years; (2) the vast majority of measurements on surface faulting were made in quick reconnaissance studies, (3) most studies measured only primary faulting, not distributed faulting, and (4) limited measurements were made in the field by hand, with aerial photographs the only imagery available (lidar, insar, DEMs, etc. had not yet been developed). As a result, the spatial extent of coseismic deformation and the accuracy and precision of displacements could not be measured as well as in the past 15-20 years. An important example of a modern, high-precision study of coseismic surface deformation is the M6.0 South Napa (California) earthquake of 2014-AUG-24. This earthquake was near the threshold of surface faulting for a strike-slip earthquake, yet with application of multiple modern imagery techniques, the field of subtle surface deformation was captured (Brocher et al., 2015). What this implies to the SURFACE project is that, when creating the SURE database, we should examine the epicentral areas of all earthquakes down to at least M6.0.

METHODS

The following list was made by searching the USGS earthquake database (http://earthquake.usgs.gov/earthquakes/search/) to find shallow (<35 km) crustal earthquakes on land that had moment magnitudes of 6.0 or larger. These earthquakes are large enough that they may have created a surface rupture trace, although the chance of geologists finding that trace varied according to the ease of access, vegetation cover, availability of topographic imagery (lidar, insar, DEMs created from photographs), and by how much the earthquake exceeded the threshold for surface rupture for its slip sense.

I performed the search one year at a time, starting with 2016 and working backwards to 2000. For displaying each year's earthquakes I accepted the default display, which showed a world map of all the M6+ earthquakes and an accompanying list. By zooming into this map, I decided whether the epicenter was on-land or offshore. My list only contains those earthquakes with epicenters onshore and hypocentral depths from 0 to 35 km. Thus, there may be some subduction-interface (megathrust) earthquakes included in the list, which would not be expected to display surface faulting.

In the file I list the slip sense, mainly done by examining the earthquake's focal mechanism. This was relatively straightforward for normal and reverse earthquakes. For strike-slip focal solutions I guesstimated the slip sense (RL, right-lateral vs. LL, left-lateral) by assuming that fault strike was parallel to the topographic lineations in the epicentral area.

I also made a half-hearted attempt to screen out aftershocks of M>6, but soon gave up on this, because of my difficulty in defining which M>6 events were aftershocks. Also, there may have been additional surface rupture from aftershocks, not that the typical post-earthquake field reconnaissance would be able to distinguish them.

Finally, for the larger earthquakes (M7+) I performed a Google search with the date, name, or magnitude of the earthquake combined with the phrases "surface rupture" or "surface faulting." The search revealed the existence of published papers describing surface faulting for many (but not all) of the M7+ earthquakes. Exceptions included events in India, Nepal, and Bhutan on the major Himalayan thrusts, which I presume were "blind" earthquakes. However, for some M7+ earthquakes I could find no mention of surface rupture, especially when the event occurred in a remote, heavily forested region. And I did not search the literature for the M&-7 earthquakes.

RESULTS

1-I was surprised to find that 90% of the shallow (<35 km) M6+ earthquake epicenters in each year were offshore. These are not contained in this list. Shallow M6+ epicenters onshore from 2000 to 2016 total 130 (roughly 8 per year).

2-Of the epicenters that were onshore, most occurred in (see tab 3 of spreadsheet, EQs by Country):
China (21)
Iran (13)
Japan (8)
Russia (8)
Pakistan (7)
Turkey (7)
New Zealand (6)
Kyrgyzstan (5)
USA (5)
Chile (5, but could include megathrust events)
Nepal (5, but could include blind thrusts)
Myanmar (4)

3-However, this spatial concentration does not exist for the M7+ earthquakes, which are scattered among countries such that in the period 2000-2016, very few countries have more than one M7+ event. This implies that the spatial clustering described in item 2, above, represents M6-7 earthquakes only. Why should M6s cluster but M7s not? One answer would be that many of M6 were aftershocks of an M7+ event.

4- Finally, for the earthquakes larger than the expected threshold for surface rupture (M=6.5) I performed a Google search with the date, name, or magnitude of the earthquake combined with the phrases "surface rupture" or "surface faulting." The search revealed the existence of published papers describing surface faulting for 10 of the 20 M7+ earthquakes. For the other 10, including events in India, Nepal, and Bhutan on the major Himalayan thrusts, I found no citations to surface rupture, so I presume were "blind" earthquakes. However, there were many other M7+ earthquakes for which I could find no mention of surface rupture (positive or negative), especially when the event occurred in a remote, heavily forested region. I did not search the literature for the M6-7 earthquakes.

CONCLUSIONS

1-The list contains 47 earthquakes of M6.5 or greater, which should have been large enough for surface rupture to occur and be found, even without using the new tools of lidar, insar, or DEMs. Of these 47 events, I could only find reference in a literature for surface faulting (either its existence or absence) for 16 of those events (about 1/3 of them). For the other 2/3 of the M6.5+ events, I could not find any reference in Google searches for any technical publication about the earthquake and surface faulting. Thus I can't tell if surface rupture was even looked for, or how it was looked for (imagery only versus recon of epicentral area).

2-To retrieve any data about surface faulting in these 31 "unreported" events, the best way is for a geologist in the epicentral country to peruse local literature sources. It may be that there were observations made of surface rupture, and even published in the gray literature, but that literature is not in English. For the 9 unreported events of M7+ (see tab EQs by Magnitude), here are the countries where no data can be found on surface rupture:
Nepal (2)
Russia (2)
Chile (1)
New Zealand (1)
Tajikistan (1)
Turkey (1)
Turkmenistan (1)

3-Likewise, there are 27 earthquakes in the list between M6.5 and M6.9. Arguably all of these should have created surface rupture. However, after briefly searching Google, I could only find surface rupture measurements from 3 of these 27 events. For an additional 2 events there were publications that stated there was no surface rupture. That means for 22 of the 27 events we don't know if there was surface rupture or not.

4-Finally, from the 2014 South Napa earthquake we know that earthquakes as small as M6.0 can have surface rupture detectable by modern techniques. In the list there are 83 events between M6.0 and M6.4. Of that number, we know that 3 had measurable surface rupture, and 1 had no rupture. As to the other 79 events we have no idea if they had rupture, or how much.