TIME-HISTORY ANALYSIS OF FAULT SCARPS AND FAULT TRACES-- A LONGER VIEW OF SEISMICITY

by

Robert E. Wallace[I]

SYNOPSIS

Time-history analysis of young faults by geologic means can add important data to the limited historic record of seismicity. As an example, in central Nevada large earthquakes are estimated to have occurred at the rate of approximately 3×10^{-5} per year per 1,000 km^2 during the last 12,000 years. Average recurrence intervals on individual fault zones are approximately 10,000 years, and some active faults may remain dormant for several times that long. Long-term characteristics of subprovinces can be interpreted. For example, the central Nevada seismic belt has been characterized by an upper limit of M7-8 for earthquakes for the past few hundred thousand years, whereas eastern Nevada and western Utah have been characterized by an upper limit of M6-7 for earthquakes during that period.

EXAMPLE OF ANALYSIS IN CENTRAL NEVADA, USA

Analysis of fault scarps in a study area of about 17,000 km^2 in north-central Nevada indicates that in the past 12,000 years seven earthquakes comparable to those of 1915 and 1954 (M = 7-8) occurred, which represents a rate of approximately 3×10^{-5} per year per 1,000 km^2. In comparison, estimates for western Nevada based on historic samples of seismicity range from 7×10^{-5} to 2×10^{-4} events per year per 1,000 km^2, depending on sampling assumptions (Ryall and Douglas, 1975, and written communication, 1976). Considering the uncertainties of both the seismological and geological approach, the differences may not be significant, but clearly both methods indicate that average recurrence intervals for large earthquakes must be of the order of thousands of years on individual faults.

At least 22 individual major fault movement events can be identified within the region (fig. 1). The age of the oldest is uncertain, but possibly it is no more than a few hundred thousand years.

Approximately 700 linear kilometres of young fault scarps were analyzed along the flanks of 13 mountains and ranges between 116°30'-118°15' W. and 40°-41° N. This area lies at the north end of the central Nevada seismic belt and within the Basin and Range tectonic province (see Slemmons, 1967). Ryall and others (1966) indicate that this belt was the most seismically active region in the Western United States between 1932 and 1961.

The estimation of earthquake magnitudes is based on the correlation of length of fault to magnitude (Bonilla, 1967 and 1970). Inasmuch as historic earthquakes in the Basin and Range province have been accompanied by complex sets of surface ruptures, a degree of interpretation is required to relate a set of scarps to a single prehistoric earthquake. The ages of the fault scarps, or parts of the scarps to be attributed to single earthquakes, are based on a variety of geochronologic criteria.

I Geologist, U.S. Geological Survey, Menlo Park, California 94025

For reconnaissance purposes, the profiles of scarps, particularly the slope angles and sharpness of the scarp crest, provide useful guides to the ages of scarps (Wallace, in press). Scarps younger than 12,000 years have characteristic slopes of 20°-25°, but slopes of older scarps have declined to only 7°-8° although the scarps still retain their sharply linear appearance on aerial photographs.

Other evidence of the age of scarps is obtained from: crosscutting relations of the high beach line of glacial Lake Lahontan (12,000± yrs B.P.), dated volcanic ash and carbonized wood occurring in fault-related sediments, vertebrate fossils, solution pitting on faulted limestone, tree rings, and potassium-argon dating of faulted volcanic rocks.

An average recurrence interval of 8,700 years is derived from the amount of offset of range-capping basalts, which are 10-14 million years old, and by assuming that great earthquakes are each accompanied by 3 m of fault offset. This length of time between large earthquakes tends to be corroborated by the length of time between the 1915 earthquake and the next previous earthquake along the Pleasant Valley fault. The next previous earthquake is suggested to have been more than 6,600 years ago, the age of Mazama ash, and possibly 12-20,000 years old, as shown by solution pitting on the fault plane exposed during that event. Some scarps may have been dormant for several times 12,000 years; for example, the fault scarp on the west flank of the Stillwater Range appears much more degraded than the wave-cut cliff at the high beach line of Lake Lahontan (12,000± yrs B.P.) which truncates the fault scarp. Many of the fault scarps display evidence of multiple offsets, and some of the older of the 22 events shown in figure 1 are based on interpretations of such complex fault scarps.

The central Nevada seismic belt appears to have been the locus of major earthquakes for at least several hundred thousand years and probably for several millions of years, but during the present century an unusual amount of seismic activity may have occurred.

Sets of faults along the base of some ranges appear to have been repeatedly active whereas over the same period of time faults along companion ranges have remained dormant. Even along single sets of range-front fault scarps, individual segments of scarps only a few kilometres long have had repeated offsets while the remaining parts of the set are inactive. For example, some short scarp segments are 50 m or more high, which is three times the maximum of 15 m recorded in historic events (Bonilla, 1970), and many times the average height of the whole set of scarps. Clearly, localized repetition of offsets is indicated. Perhaps single offsets may not always relieve the accumulated elastic strain, and a cluster of events is required to do so.

An overview map of active and potentially active faults in the United States being prepared by the staff of the U.S. Geological Survey demonstrates gross regional differences in potential seismicity. The probability, magnitude to be expected, and style of deformation are suggested by the habits of faulting in different regions. For example, in that part of the Great Basin province that lies in eastern Nevada and western Utah, young fault scarps (<500,000± years) are generally only a few kilometres long, although commonly these scarps occur along much longer fault traces believed to be several million years old. The fault history over the past few hundred thousand

years, as derived from fault length-magnitude relationships, suggests that in that region most earthquakes did not exceed magnitude 6 or 7. In contrast, in central and western Nevada, young fault scarps several tens of kilometres long are very common, suggesting a long-term history of earthquakes having an upper limit in the range of magnitude 7-8.

ANALYSIS OF OTHER AREAS

Similar types of time-history analysis are also in progress on strike-slip and reverse faults in the Western United States and Alaska. Such studies of fault scarp and fault trace characteristics and of the time sequence of their development can provide a much clearer view of average recurrence intervals of earthquakes, habits of clustering of seismic events in time and space, and the migration of these events. These data can help in refining seismic zoning, in estimating seismic risk in a given region, and in understanding the origin and mechanical behavior of large tectonic blocks and provinces.

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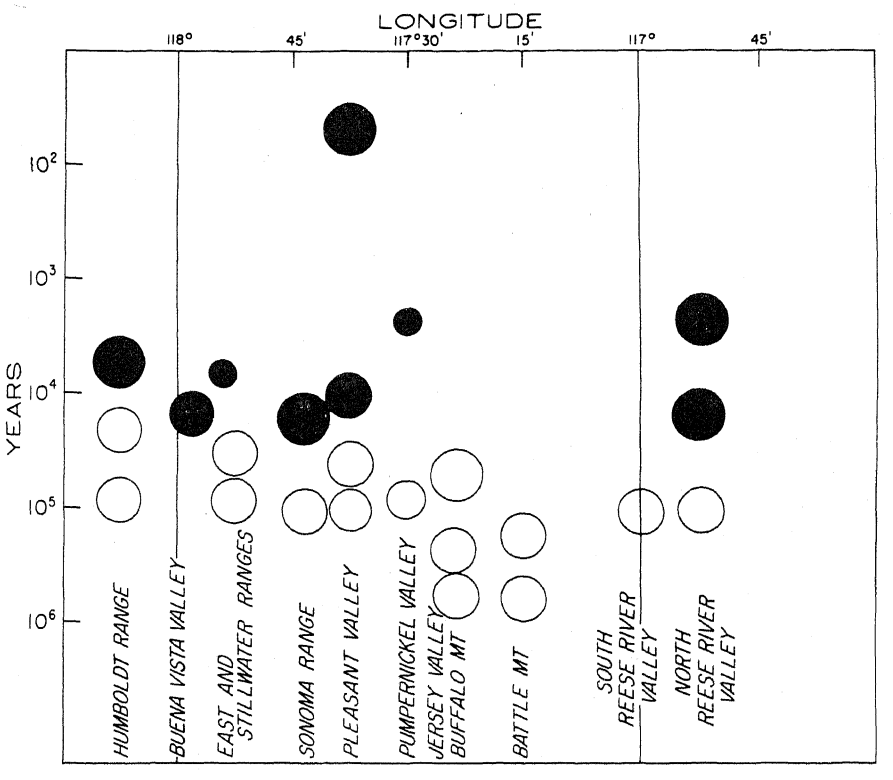

Figure 1. Distribution of fault scarps by age and longitude between 40° and 41° N. in north-central Nevada. Solid circles indicate scarps <12,000 years old. Open circles indicate scarps >12,000 years old. Small circles indicate scarps whose length suggests earthquakes <7M.