Paleo-Earthquake Study on Bedrock Fault Surface in Shanxi Graben

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Abstract: Paleo-earthquake research is the most effective method to obtain relatively complete seismic records and expand the history of seismic records. At present, the most commonly used trenching technique cannot be used to do paleo-earthquake research in bedrock areas. The quantitative analysis of morphologic characteristics of bedrock fault surfaces and cosmogenic nuclides dating techniques may be useful approaches to study faulting history and identify paleo-earthquakes, effective complements to trenching techniques, especially to identify paleo-earthquakes in a bedrock area where trenching technique cannot be applied. Continuous weathering and periodic seismic activity result in significant vertical zoning of bedrock fault surface, and each zoning band is related to an earthquake. The correlation between the morphologic parameter and exposure age is fitted based on the morphologic analysis and cosmogenic nuclides dating of several test fault surface. According to this correlation, we obtain the paleo-earthquake series of the target fault and the earthquake spatio-temporal distribution in the study area. Finally, combined with the results of previous trenching paleo-seismological researches, we construct a recurrence model of strong earthquakes to the test study area and target faults. We calculate the 2D fractal dimension of three bedrock fault surfaces on the Huoshan piedmont fault in the Shanxi Graben, China using the isotropic empirical variogram. We show that the fractal dimension varies systematically with height above the base of the fault surface exposures, indicating a segmentation of the fault surface morphology. We interpret this segmentation as being due to different exposure duration of parallel fault surface bands, caused by periodical earthquakes, and discontinuous weathering. We take the average of fractal dimensions of each band as a characteristic value to describe its surface morphology, which can be used to estimate the exposure duration of the fault surface band and then the occurrence time of the earthquake that exposed the band. Moreover, the average width of those fault surface bands can also be regarded as an approximate vertical coseismic displacement of characteristic earthquake similar to the Hongdong M8 earthquake of 1303. Based on the segmentation of quantitative morphology of the three fault surfaces on the Huoshan piedmont fault, we identify three earthquake events. The coseismic vertical displacement of the characteristic earthquake on theHuoshan piedmont fault is estimated to be 3 - 4m, the average width of these fault surface bands. Gaps with a width of 0.1–0.3m between two adjacent bands, in which the fractal value increases gradually with fault surface height, are inferred to be caused by weathering between two earthquakes or interseismic slip on the fault.

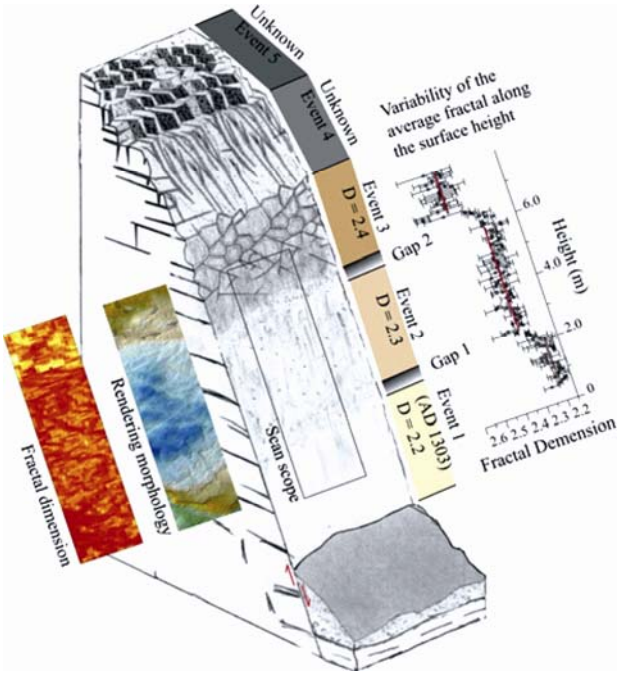

Fig. 1. Evolutionary model of fault scarp surface, showing five weathering bands corresponding to five different exposure times (modified from model of Giaccio et al, 2002). The two higher bands have conspicuous weathering morphological feature identified by naked eye easily; while the three lower bands have no conspicuous weathering morphological feature identified by naked eye, and similar dip angle as original fault dip angle. The quantitative morphology applied in our study can identify the three lower bands. The rectangle on the fault scarp surface shows the scan scope, and the two color rectangles on the left show fractal dimension and rendering morphology, respectively. The characteristic fractal of the three lower bands are demonstrated by color bars and scatter diagrams on the right.

Key words: Paleoearthquake, Active fault, Bedrock fault scarp, Shanxi Graben

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