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The Principal Component Analysis of X-Ray Fluorescence Spectrometry Data as a Tool for Paleoseismic Research

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To document the magnitude of displacement in past faulting events, observed in excavated paleoseismological trenches across faults, stratigraphic and structural relationships imprinted on the walls should be interpreted. Often, the interpretation is not straightforward. Stratigraphic units on the upthrown block may be subjected to subaerial erosion, while the downthrown block is sometimes poorly stratified with few stratigraphic horizons. Since it is difficult to correlate the lithologic units on the opposite sides of the fault, the reconstruction of past displacements is an equally arduous task.

In this work, samples from a recently excavated paleoseismological trench were collected and analyzed with the method of X-ray Fluorescence (XRF) Spectrometry, in order to assess their elemental composition. The XRF data were submitted to Principal Component Analysis (PCA), which is a well-established dimension-reducing statistical technique, applied for pattern recognition in multivariate datasets. The statistical handling aimed to distinguish the base of scarp-derived colluvium(s) from the top of the prefaulting deposits of the downthrown block and infer from which part of the upthrown fault block scarp-derived colluvium and colluvial wedges, parts of the downthrown block were derived and thus estimate displacement.

The paleoseismological trench was excavated in Gyrtoni, Larissa, Greece. The excavation yielded excellent results in relation to the recent activity of the Gyrtoni Fault. The south facing Gyrtoni Fault is $\sim$12-13 km long and defines the north boundary of the Middle-Late Quaternary Tyrnavos Basin, at a distance of ca. 10 km from the city of Larissa. The walls of the trench were cleaned and mapped in detail. The footwall of the fault consists of well stratified lagustrine deposits, while the hanging wall consists of poorly stratified scarp-derived deposits. The initial preliminary interpretation of the trench wall structure provided indications of recent reactivations of the fault.

Seven samples, one for each lithologic unit, were collected from the upthrown fault block and 10 samples were collected from the downthrown fault block. The samples were dried, pulverized and pressed into standard pellets before carrying out XRF spectrometry measurements. Radioisotope sources (^{109}Cd and ^{241}Am) were used for sample excitation, while X-ray spectra were acquired using a Si(Li) detector coupled with adequate electronics. The concentrations of 17 minor and trace elements (K, Ca, Ti, Cr, Mn, Fe, Cu, Ni, Zn, Rb, Sr, Y, Zr, Ba, La, Ce, Nd) were thus determined. To identify samples of similar composition, the elemental data were treated by PCA using the STATISTICA 8 Statistical Software. The PC score-plots revealed a widely scattered compositional pattern. However, three distinct chemical groups were identified, associated with differences in elemental concentrations. The PCA grouping, combined with geological criteria, allowed distinguishing the colluvial deposits on the downthrown fault block and inferring the provenance of the scarp-derived colluvium and colluvial wedges. An ongoing mineralogical analysis by X-ray diffraction is expected to provide further arguments in this direction.

The results indicate that the XRF analysis combined with Principal Component Analysis can serve as a useful tool for paleoseismological research.