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Unexpected earthquake hazard revealed by Holocene rupture on the Kenchreai Fault (central Greece): Implications for weak sub-fault shear zones

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ABSTRACT

High-resolution elevation models, palaeoseismic trenching, and Quaternary dating demonstrate that the Kenchreai Fault in the eastern Gulf of Corinth (Greece) has ruptured in the Holocene. Along with the adjacent Pisia and Heraion Faults (which ruptured in 1981), our results indicate the presence of closely-spaced and parallel normal faults that are simultaneously active, but at different rates. Such a configuration allows us to address one of the major questions in understanding the earthquake cycle, specifically what controls the distribution of interseismic strain accumulation? Our results imply that the interseismic loading and subsequent earthquakes on these faults are governed by weak shear zones in the underlying ductile crust. In addition, the identification of significant earthquake slip on a fault that does not dominate the late Quaternary geomorphology or vertical coastal motions in the region provides an important lesson in earthquake hazard assessment.

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1. Introduction

Horizontal extension by normal faulting often results in arrays of fault-bounded blocks that have rotated about horizontal axes as their bounding faults slip (so-called 'domino' or 'bookshelf' faulting) (e.g. Gilbert, 1928; Proffett, 1977; Morton and Black, 1975; Jackson and McKenzie, 1983). However, questions remain over what controls whether faults positioned across-strike from each other are active simultaneously or sequentially, and how this may vary between different extensional settings (e.g. Jackson et al., 1982; Dart et al., 1995). Additionally, in cases where the location of dominant slip activity migrates across-strike between faults, it is not known whether this transition is sudden or gradual, or what controls the direction of migration (e.g. Goldsworthy and Jackson, 2001). Addressing these questions will reveal important information about the mechanics and behaviour of faults, and will also highlight whether multiple faults in arrays of parallel structures need to be considered as sources of earthquake hazard. In addition, understanding the behaviour of arrays of faults will allow us to probe the properties of the underlying ductile layer. Specifically, we can address the controversy of whether strain accumulation at faults is governed by flow in a laterally-homogeneous viscoelastic material (e.g. Meade et al., 2013), or whether lateral contrasts in effective viscosity are the dominant control (e.g. Yamasaki et al., 2014). We address these questions by making new observations of Holocene fault slip on the Kenchreai Fault on the south side of the Gulf of Corinth in central Greece.

The Kenchreai Fault bounds the south side of the isthmus between the Gulf of Corinth and the Saronic Gulf (Fig. 1). The northern, hangingwall, side of the fault is occupied by the Corinth Terraces – a series of marine terraces, dating from ~0.5 Ma to the present, that have been uplifted by motion on the Heraion (also known as Xylokastro) and Pisia faults to the north (e.g. Armijo et al., 1996). This northern fault system ruptured in M_w6.7 and 6.4 earthquakes in 1981 (e.g. Jackson et al., 1982). The uplift of the Corinth Terraces relative to the sea-level highstands at which they formed (e.g. Armijo et al., 1996) shows that the Heraion and Pisia faults have been more active over the last ~400 kyr than the Kenchreai and Loutraki Faults, motion on which would produce hangingwall subsidence in the region of the terraces. It is likely that the Kenchreai Fault was the most active fault in the region in the early/mid Pleistocene, because the sediments currently exposed in the cutting of the Corinth Canal (Fig. 1; Collier and Dart, 1991) represent a series of climatically-controlled sea-

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