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EARTHQUAKE HAZARDS AND HIDDEN RISKS ALONG THE NEW SILK ROADS

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Abstract: *The coming decade will see continued rapid infrastructure and urban growth across Central Asia, spurred partly by the need to supply natural gas and other raw materials. These regions, however, largely lack pre-existing detailed knowledge of active fault distribution and related landslides, potentially introducing unmodelled risks from shaking and ground rupture. In this presentation I highlight recent studies by the Active Tectonics and Earthquakes Research Group, Oxford University, which bring together field-based, remote-sensing, and seismological insights to build improved characterisation of active faults. As examples we show ongoing work in Azerbaijan to identify major active faults within the Kura Basin in proximity to urban centres and infrastructure. In a new project in Uzbekistan, we uncover sources of earthquake hazard near the UNESCO world heritage centre of Samarkand. In Kazakhstan we have recognised that the main range-front active fault, in addition to posing significant shaking risk to the city of Almaty (2 Million population) through which it passes, is also coincident for 100 km with the main soviet-era canal supplying water to the city and to surrounding agricultural land. We are undertaking forensic investigation of the major historical earthquakes, many of whose sources are unknown, to build a better understanding of vulnerability in cities including Asgabat (Turkmenistan), Tashkent (Uzbekistan), Almaty (Kazakhstan), Bishkek (Kyrgyzstan) and Dushanbe (Tajikistan). Our aim is to develop state-of-the-art underpinning information on active faults, their earthquake potential, and identification of those places where specific vulnerabilities may exist. These studies will aid feasibility studies for future infrastructure and development projects, and identify potential strategies for the remediation of existing structures. We thank our collaborators in partner institutes across Asia. Also the NATO SPS program, the Leverhulme Trust, GEM, and UKRI through the NERC Innovation, GCRF, the NERC-ESRC 'Earthquakes Without Frontiers' program, and the COMET centre.*

Earthquake hazards in central Asia – from active fault mapping to detailed source investigations

Active faulting within continental interiors is spread across very wide regions, and with intervals of hundreds, or even thousands of years between large earthquakes in any one area, such that their identification requires forensic study of recent, historic, and prehistoric earthquakes, and comprehensive mapping of active faults from their expression in the landscape, which are all of vital importance in the assessment of the present-day hazard.

To provide sufficient detail over the necessarily wide areas requires sustained and dedicated research. It also requires the integration of remote sensing, geophysical methods, geological investigation, and careful interpretation of historical and archaeological sources.

The last century has seen unprecedented urban growth in regions of earthquake hazard throughout Central Asia. For example Almaty, Kazakhstan, with a population of 2 Million, was badly damaged by a magnitude 7.3 event in 1887, and two extremely large events of magnitude 8 that struck the city in 1889 and 1911 (e.g. Abdrakhmatov et al., 2016). Ashgabat, the capital city of Turkmenistan, was destroyed with much loss of life in a poorly understood earthquake in 1948 (e.g. Dodds et al., 2021). Hazards are spread across the Central Asia region, with large 20th century earthquakes also in Kyrgyzstan, Tajikistan, and Uzbekistan (e.g. Figure 1).

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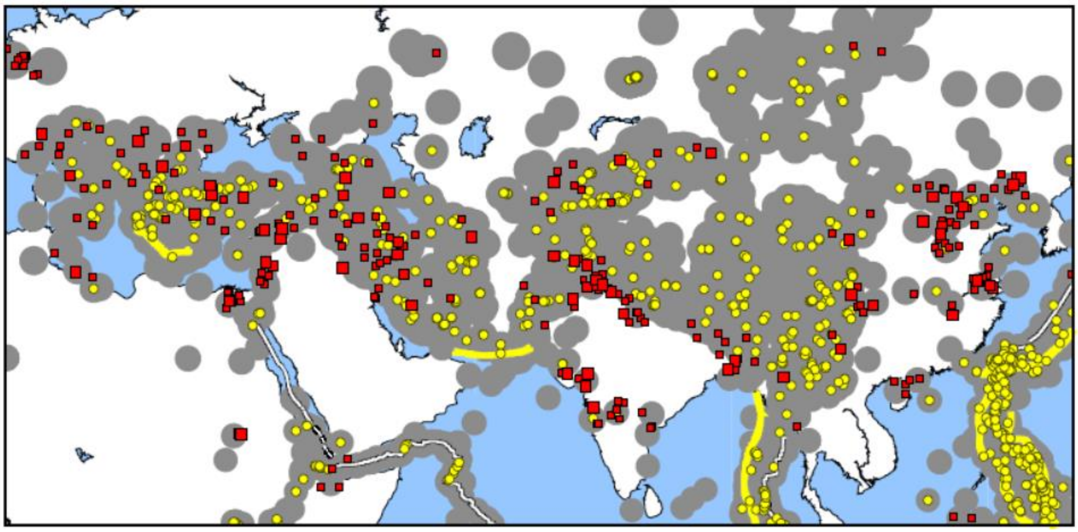

Figure 1. *The majority of major population sites across Eurasia (red squares, scaled by population size) lie in zones of earthquake hazard (as represented by the grey region, showing areas within 150 km of instrumental shallow earthquakes > Mw 5, shown as yellow dots. Image adapted from Earthquakes without Frontiers program / Prof. Philip England.*

We are building an understanding of the major historical and prehistorical earthquakes of central Asia within the EROICA project (Earthquake Ruptures of Iran and Central Asia), a multi-year program funded by the Leverhulme Trust. Within this program we have designed and applied a targeted workflow that combines remote-sensing and field-based geological investigation (Abdrakhmatov et al., 2020), along with seismological study using digitised heritage paper records (e.g. Ou et al., 2020). The determination of earthquake sources, rupture length and slip amounts feed into improved understanding of earthquake scaling within continental interior regions, and also allow us to better delimit prehistoric earthquake events from their expression in the landscape, and through paleoseismic trenching. We are presently involved in projects that are widely dispersed across Asia, working with colleagues in national Institutes and universities (e.g. Figure 2).

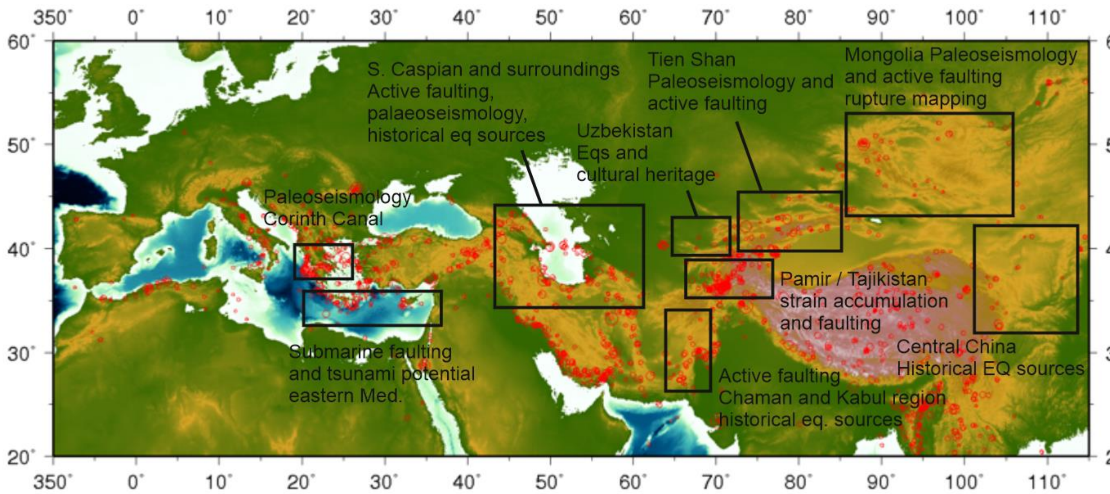

Figure 2. Geographical spread of current projects within the EROICA program

We have given particular emphasis in our studies to those regions that are most vulnerable to earthquake risk, and where there has been relatively less earthquake geological research in recent decades. An example is Almaty, Kazakhstan, a rapidly-growing urban centre of ~2 Million (e.g. Abdrakhmatov, et al., 2016; Grutzner et al., 2017; Amey et al., 2021). We have identified the sources of historical large earthquakes, including the M8.3 Chilik earthquake of 1889, and have undertaken paleoseismic studies of these faults and others. Our paleoseismic studies are on faults with no historical record of seismicity, including the Zailisky fault that cuts through the urban centre of Almaty (Figure 3).

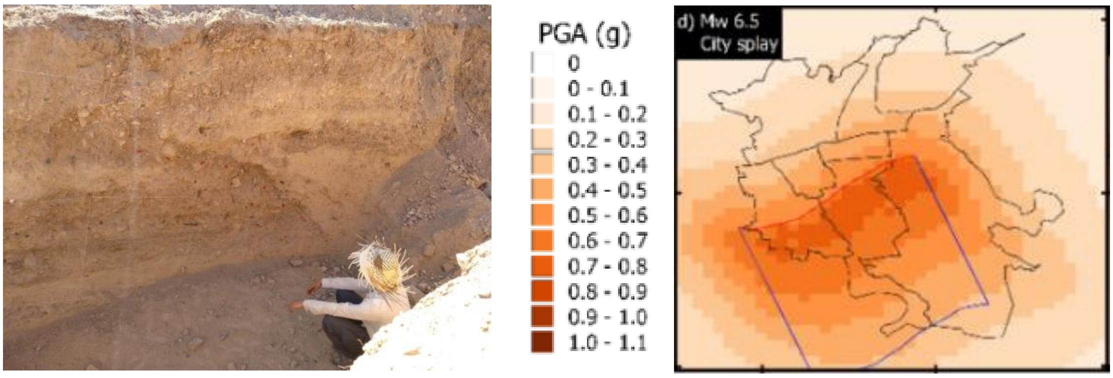

Figure 3. Paleoseismic trench exposing two surface-rupturing earthquakes on the Zailisky thrust, which extends through the urban centre of Almaty, Kazakhstan (Photo Aidyn Mukambayev, National Nuclear Center, Kazakhstan). Fault mapping and paleoseismic trenching are used as the basis of earthquake scenarios, as in the example shown at right (from Amey et al., 2021)

We combine detailed site-specific fault investigation with regional mapping to infer regional tectonic frameworks, which enable us to assess distributions of earthquake sources, and also the types and styles of deformation. A current focus of this work is the South Caspian basin, and surrounding onshore areas in Azerbaijan, Turkmenistan, and Iran (figure 4). Through this work in partnership with industry, we have mapped a number of unknown or poorly known fault systems, and uncovered evidence for repeated large magnitude earthquakes in regions of subdued recent or historical seismicity.

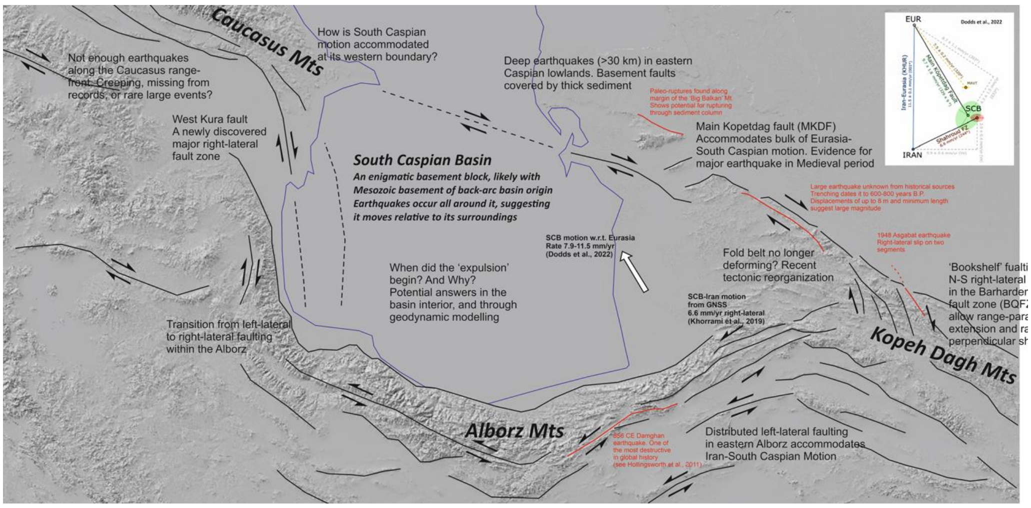

Figure 4. Active faulting of the South Caspian region, fusing remote-sensing, earthquake seismology, field-based geology, and subsurface geophysics

A common thread through all of our work is the need to combine seismological observations of recent earthquakes with archives developed from historical sources, and from prehistoric records preserved in landscapes and extracted from paleoseismic excavations. The importance of these long-time-duration records is particularly important in continental interior settings, where recurrence intervals far exceed instrumental and even historical completeness, where earthquake styles and sizes may show departures from globally-averaged scaling relationships, and where there may be a strong time-dependence to earthquake occurrence. The rapid and developing pace of urban and infrastructure growth demands continued efforts in the identification and characterisation of hazardous faults across Silk routes of Asia, combined with a need for the means of efficient transfer of geological knowledge to industry, governments, and international agencies.

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