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A survey of the induced seismic responses to fluid injection in geothermal and CO_2 reservoirs in Europe

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The paper documents 41 European case histories that describe the seismogenic response of crystalline and sedimentary rocks to fluid injection. It is part of an on-going study to identify factors that have a bearing on the seismic hazard associated with fluid injection. The data generally support the view that injection in sedimentary rocks tends to be less seismogenic than in crystalline rocks. In both cases, the presence of faults near the wells that allow pressures to penetrate significant distances vertically and laterally can be expected to increase the risk of producing felt events. All cases of injection into crystalline rocks produce seismic events, albeit usually of non-damaging magnitudes, and all crystalline rock masses were found to be critically stressed, regardless of the strength of their seismogenic responses to injection. Thus, these data suggest that criticality of stress, whilst a necessary condition for producing earthquakes that would disturb (or be felt by) the local population, is not a sufficient condition. The present data are not fully consistent with the concept that injection in to deeper crystalline formations tends to produce larger magnitude events. The data are too few to evaluate the combined effect of depth and injected fluid volume on the size of the largest events. Injection at sites with low natural seismicity, defined by the expectation that the local peak ground acceleration has less than a 10% chance of exceeding 0.08g in 50 years, has not produced felt events. Although the database is limited, this suggests that low natural seismicity, corresponding to hazard levels below 0.07g, may be a useful indicator of a low propensity for fluid injection to produce felt or damaging events. However, higher values do not necessarily imply a high propensity.