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Radon-222: A Potential Short-Term Earthquake Precursor

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advanced approach is the detrended uctuation analysis (DFA) [27,57]. According to the reports [27,57] and several other papers [38,51] the detrended uctuation analysis is the most advantageous technique to trace the long-memory of a system driven to rupture. Signi cant other techniques are the time-evolution of the fractal dimension [26] and the Hurst exponent [25-27,57] and the temporal changes of various metrics of entropy [26]. Note that the techniques can trace patterns of long-memory that are hidden in the pre-earthquake time-series. ey can also identify features related to the self-organization of the earthquake generating system. It is also important to note that the vast majority of papers of Table 1 refer to measurement of radon in soil. Only some papers refer to radon in underground or thermal water and only one to radon detected in atmosphere prior to earthquakes [62]. Note that in this paper advanced Fourier based approach was implemented for a signi cant long-lasting signal retrieved prior to the Kobe earthquake, Japan.

Various physical mechanisms have been reported to relate the sub-surface physical changes with the variation in radon emanations [25]. Regarding modelling, the available models propose explanations in terms of strain changes within the earth's crust during preparation of earthquakes [5,33,34,40]. It is the displacement of rock mass under tectonic stress that opens up various pathways and exposes new surfaces when cracks open. e stress-strain developed within the earth's crust before earthquakes leads to changes in gas transportation from the deep earth to surface [41,42]. As a result, unusual quantities of radon emerge out of the pores and fractures of the rocks on the surface. Due to the seismic activity, changes in underground uid ow may also render anomalous changes in concentration of radon and its progeny [43]. Under the so called compression model, according to [63] and [64] a small change in velocity of gas into or out of the ground causes a signi cant change in radon concentration at shallow soil depth as changes in gas ow disturb the strong radon concentration gradient that exists between the soil and the atmosphere. A slight compression of pore volume causes gas to ow out of the soil resulting to an increase in radon level. Similarly, when pore volume increases, gas ows into the soil from the atmosphere. us, an increased radon concentration occurs in the region of compression and radon concentration decreases in the region of dilation. As small changes in gas ow velocity causes signi cant change in radon concentration, soil radon monitoring is thus an important way to detect the changes in compression or dilation associated with an earthquake event.

Among the various theoretical models, the dilatancy di usion model proposed by Martinelli [5,65] is a noteworthy approach. According to this model [5,25-27] the earthquake generating medium is considered to consist of porous cracked saturated rocks. When a tectonic stress develops, the cracks extend and appear near the pore with the opening of favourably oriented cracks [5,25-27]. As a result, the pore pressure decreases in the total preparation zone and water from surrounding medium di uses into the zone. At the end of the di usion period the main rupture occurs due to the appearance of pore pressure and increase in cracks [5,25-27].

A well-accepted model is the the Crack-Avalanche model [5,25-27,66]. According to the Crack-Avalanche model as tectonic stress increases during the earthquake preparation, a zone of cracked rocks is formed in the region of a future earthquake focal zone under the in uence of the tectonic stresses. In the study of the surrounding medium this region may be considered as a solid inclusion with altered moduli. e inclusion appearance causes a redistribution of the stresses accompanied by corresponding deformations. As the tectonic stresses change with time, the shape and size of the zone change as we According to the theory of stress corrosion, the anomalous behavior of radon concentration may be associated with this slow crack growth,

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