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Use of Deformation Based Reservoir Monitoring for Early Warning Leak Detection

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Surface deformation monitoring has a number of well known advantages for monitoring subsurface strain changes induced by processes including fluid flow, fracturing, earthquakes, magmatic movement, and injection and production operations. One of the primary benefits is that surface deformation increases quickly in magnitude and changes in spatial distribution as the source of the strain approaches the surface. This allows deformation, whether measured by techniques such as interferometric synthetic-aperture radar (InSAR), tiltmeters, GPS, or a combination thereof, to function as an effective early warning of impending or potential surface breach caused by cap rock or well casing failure. In particular, this type of monitoring has proven beneficial at heavy oil production sites using steam injection and at waste injection sites requiring monitoring to help ensure containment.
This paper discusses a theoretical approach to determine the sensitivity of surface deformation measurements to changes in depth of a subsurface fluid. The sensitivity is a function of a number of parameters, including the original fluid depth, volume of fluid, and uncertainty of surface-deformation measurements. Measurements can also be affected by the geologic structure if significant modulus contrasts are present. The results of this study can be used to determine whether surface deformation monitoring is a valid approach to verify cap rock integrity and which types of measurements are required to obtain the necessary resolution. It also provides a basis for selecting the area to be covered by monitoring and the minimum density of monitoring stations to help ensure leaks cannot occur in an unmonitored zone between stations.