Mechanisms for earth fissure formation in heavily pumped basins

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Abstract Earth fissures are perhaps the most deleterious by-products of excessive groundwater exploitation in many subsidence-prone arid-zone sedimentary basins. These features have long been associated with differential land subsidence caused by changes in the thickness of compacting sediments, abrupt changes in stratigraphy, or by large changes in vertical effective stress resulting from large drawdown gradients. However, it is recognized that pumping-induced earth fissures can and do form in areas far from the centre of pumping where drawdowns are small and the changes in drawdown are even smaller. The key to understanding where and why fissures form is to first recognize that subsidence is a three-dimensional phenomenon; horizontal strain can play a vital, if not a dominant, role in invoking fissure formation, yet this important component is often ignored or considered irrelevant. The second key is the shape and properties of the boundary conditions. Boundary conditions here refer to any feature that affects the transmission of stress and strain in three dimensions. Thus, boundaries can be represented as faults, bedrock knobs, basin edges, or other heterogeneities causing stratigraphic changes. It is clear that such boundaries would cause abrupt changes in physical parameters such as bulk modulus and hydraulic conductivity. However, the shape of the boundary is also important relative to the stress regime imposed by pumping. Subvertical faults, thinning aquifers and bedrock knobs can cause an unequal vertical distribution of horizontal strain, which results in rotation of the adjacent sediments that can cause zones of localized compression and zones of localized extension. These zones of extension can migrate upward and exceed the failure criterion in the weak vadose zone, resulting in a fissure that can originate anywhere between the saturated zone and land surface.

Key words earth fissures; land subsidence; aquifer mechanics; faults; sedimentary basins