Statistical Pattern Analysis of the Nullarbor Plain (Southern Australia): An Analog for Subsurface Karst

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Abstract

Karst pose multiple challenges to hydrocarbon reservoir development by promoting reservoir heterogeneity, hindering seismic interpretation due to low resolution and producing drilling hazards. To understand the controls on sinkhole, or doline, lateral distribution and morphometrics, we turn to an analog. The Nullarbor Plain (southern Australia) is an excellent natural laboratory to study surficial karst because it is huge, the largest exposed limestone terrace on Earth, and it is arid, ideal for remote sensing. For this study, we selected five focus areas, each covering 500 sq. km, distributed across the Nullarbor to capture a broad diversity in the character of surficial karst. For each area, we have assembled three remote sensing datasets -visible-NIR Pléiades satellite imagery (1 m resolution), digital terrain models (DTMs, with a 10m spatial resolution), and airborne Total Magnetic Intensity (TMI) surfaces (80 m resolution). A pattern recognition algorithm was applied to the DTM to characterize depressions. The resulting doline populations were manually cross-checked with both DTMs from which they were extracted and the Pléiades imagery. TMI data was processed with a total horizontal derivative and utilized to map dolines infilled with sediment along with basement faults. A range of spatial statistics were deployed to compare and contrast the patterning of dolines between the five focus areas, explore their relationships to faults and fracture networks, relationship to calcareous ridges and swales (remnants of now eroded dunes), and to the present-day topography of the plain. There are at least three important learnings from the study so far. The first is that

traditional terrain-model analysis can greatly underestimate surficial karst systems because many dolines are infilled with sediment and lack a topographic signature. However, these can be mapped through analysis of airborne TMI data. The second learning is the patterning of karst on the Nullarbor Plain is non-random and instead guided by faults, fractures, as well as existing and paleo (i.e. now eroded) topography. These features exert meaningful control on the placement, clustering, size, shape, and orientation of dolines. The third learning is analyses from the Nullarbor suggest predictive subsurface models of karst distribution can be developed from attributes that are routinely extracted from seismic.