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# Imaging the subsurface structure of pit craters

**Craig Magee**[1], Christopher A-L Jackson[2], Corbin L Kling[3], and Paul K Byrne[4]
[1]University of Leeds, Leeds, United Kingdom of Great Britain – England, Scotland, Wales (c.magee@leeds.ac.uk)
[2]Department of Earth and Environmental Sciences, The University of Manchester, Williamson Building, Oxford Road, Manchester, M13 9PL, UK
[3]Center for Earth and Planetary Studies, Smithsonian Institution, Washington, DC 20560
[4]Planetary Research Group, Department of Marine, Earth, and Atmospheric Sciences, North Carolina State Univer-sity, Raleigh, NC 27695, USA

Pit craters are enigmatic sub-circular depressions observed on rocky and icy planetary bodies across the Solar System. These craters do not primarily form during catastrophic impact or the forcible eruption of subsurface materials, but likely due to collapse of subsurface cavities following fluid (e.g., magma) movement and/or extensional tectonics. Pit craters thus provide important surficial records of otherwise inaccessible subsurface processes. However, unlocking these pit crater archives is difficult because we do not know how their surface expression relates to their subsurface structure or driving mechanisms. As such, there is a variety of hypotheses concerning pit crater formation, which variously relate cavity collapse to: (i) opening of dilatational jogs during faulting; (ii) tensile fracturing; (iii) karst development; (iv) permafrost melting; (v) lava tube evacuation; (vi) volatile release from dyke tip process zones; (vii) pressure waning behind a propagating dike tip; (viii) migration of magma away from a reservoir; and/or (ix) hydrothermal fluid movement inducing host rock porosity collapse. Validating whether these proposed mechanisms can drive pit crater formation and, if so, identifying how the physical characteristics of pits can be used to infer their driving mechanisms, is critical to probing subsurface processes on Earth and other planetary bodies.

Here we use seismic reflection data from the North Carnarvon Basin offshore NW Australia, which provides ultra-sound like images of Earth's subsurface, to characterize the subsurface structure of natural pit craters. We extracted geometrical data for 61 pits, and find that they are broadly cylindrical, with some displaying an inverted conical (trumpet-like) morphology at their tops. Fifty-six pit craters, which are sub-circular and have widths of ~150–740 m, extend down ~500 m to and are aligned in chains above the upper tips of dikes; crater depths are ~12–225 m. These dike-related pit craters occur within long, linear graben interpreted to be bound by dyke-induced normal faults. Five pit craters, which are ~140–740 m wide and ~32–107 m deep, formed independent of dykes and are associated only with tectonic normal faults. Our preliminary data reveal a moderate, positive correlation between crater width and depth but there is no distinction between the depth and width trends of pit craters associated with dikes and those with tectonic normal faults. To test whether our quantitative data can be used to inform interpretation of pit craters observed on other planetary bodies, we compare their morphology to those imaged in

Noctis Labyrinthus on Mars; there are >200 pit craters here, most of which occur in chains, with widths ranging from 369–11743 m and depths from 1–1858 m.

Overall, we show reflection seismology is a powerful tool for studying the three-dimensional geometry of pit craters, with which we can test pit crater formation mechanisms. We anticipate future seismic-based studies will improve our understanding of how the surface expressions of pit craters (either in subaerial or submarine settings) can be used to reconstruct subsurface structures and processes on other planetary bodies, where such subsurface information is not currently available.