# Discovery of a 15-kilometer-wide comet impact crater candidate in western Saudi Arabia

Abdulrahman F. Toonsi
aftoonsi@icloud.com
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**Abstract**
There are few reports on impact craters in Saudi Arabia. This paper aims to fill a gap in the literature in this area. Using satellite imaging, a circular structure with a diameter of approximately 15 kilometers was detected on the edge of Harrat Rahat volcanic field in western Saudi Arabia. Fieldwork showed that the circular structure is a newly-discovered comet impact crater candidate, this theory is aided by the presence of shock metamorphic features such as planar fractures in quartz grains and impact breccia. This impact crater candidate could be one of the largest exposed and preserved impact craters in Saudi Arabia.

## Introduction

Impact structures are geological structures caused by extraterrestrial impacts such as asteroids and comets. When an impact occurs, a large mass of rock is vaporized and is subjected to large amounts of heat and pressure. The impact also breaks the rock beneath it and forces the broken shards together to form impact breccia. In order to prove impact events, certain geological features must be present. These include: shocked quartz (quartz with planar features), shatter cones and impact breccia. There are many terrestrial impact craters discovered and much more yet to be discovered (French, Bevan, and Koeberl, 2009, 123-70).

## Methods

This paper describes the discovery of a large previously unknown impact crater candidate in western Saudi Arabia, on the eastern edge of Harat Rahat, which is a well-known volcanic field in the area.
The search for terrestrial impact sites was conducted by using Google Earth satellite imagery. After the circular feature was identified, geological maps created by the Saudi Geological Survey were reviewed to check the general geology of the area. After that, the site was visited and rock and sand samples were taken from 5 different locations around the crater rim. See satellite images in figures 1-3.

*Grade 10 student, Jeddah, Saudi Arabia.

**Figure 1.** The image above shows sample locations from different areas in the crate rim

**Figure 2.** The image above shows a comparison of the impact crater candidate(left) described in this paper compared to the Al Wahba volcanic crater(right). It highlights the difference in size and rules out the possibility that the crater on the left is of volcanic origin.

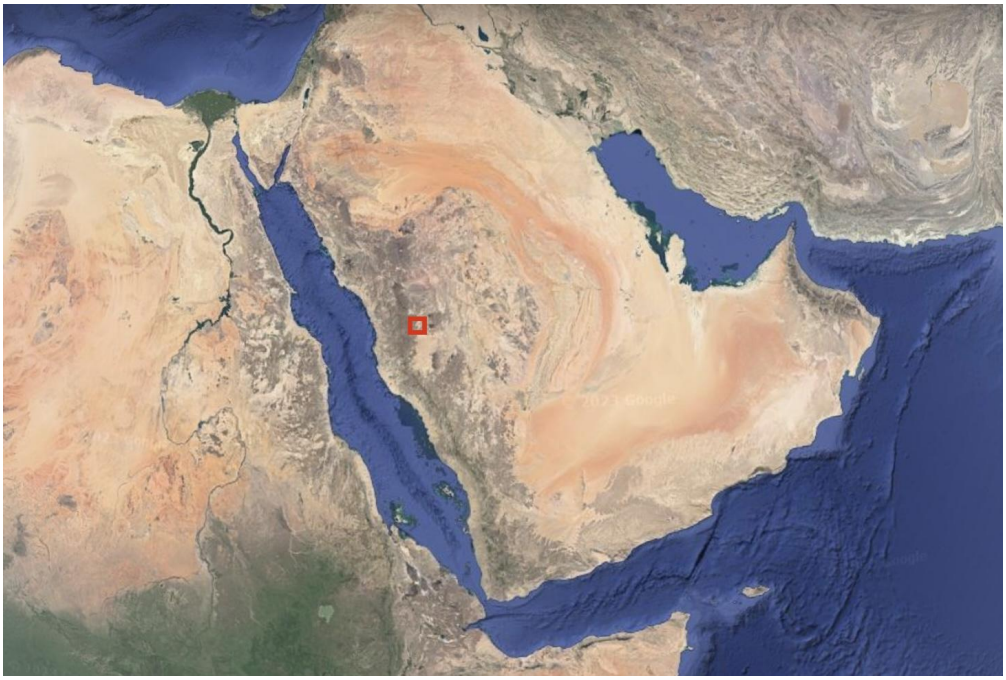

**Figure 3.** The image above shows the study area where the crater is located

Sand samples were taken from the deposits of seasonal streams coming from the crater rim in order to locate quartz grains with planar features. Microscopic images of sand samples were taken with an optical microscope with a magnification power of 40X to identify quartz grain with planar features (PFs).

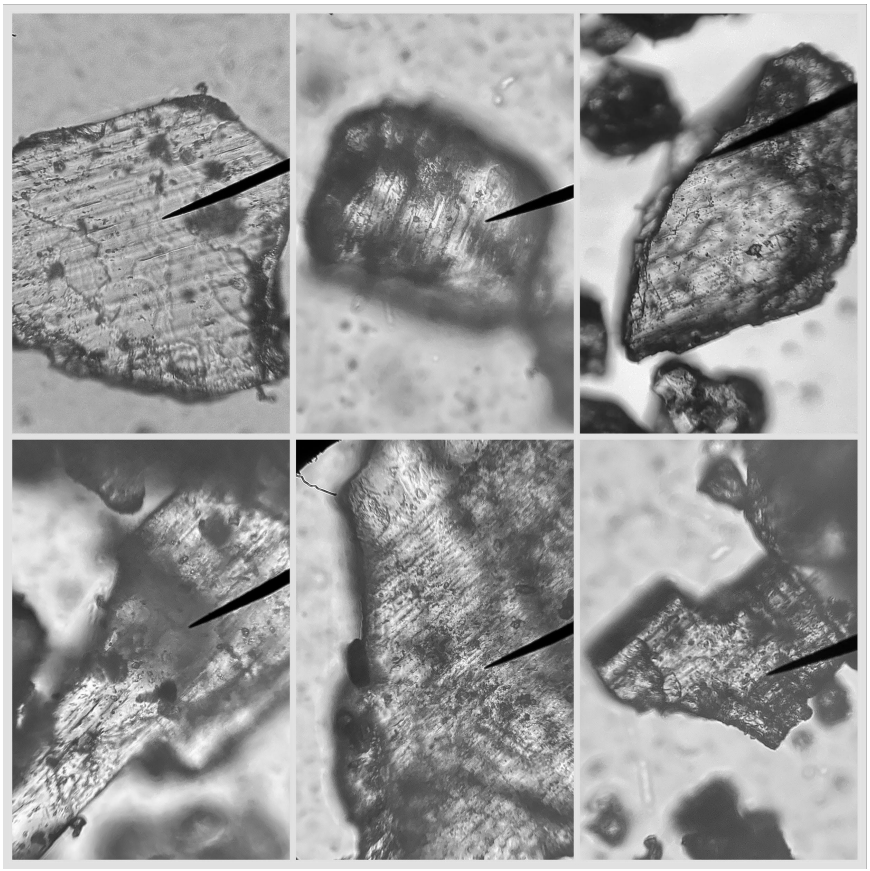

**Figure 4**: Planar features in 6 grains of quartz which is evidence of shock metamorphism, these samples were taken from a small gully originating from the crater rim.

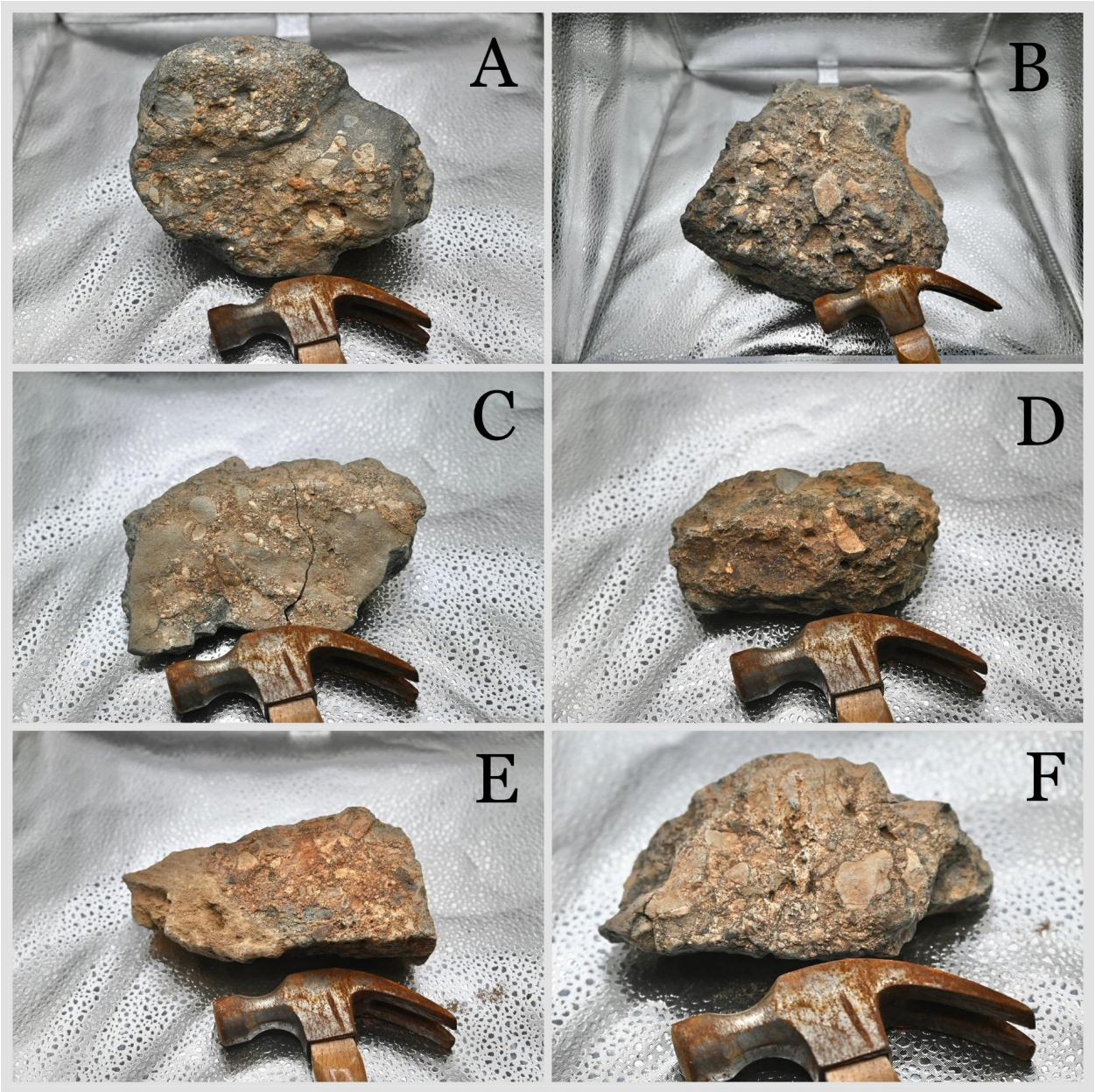


**Figure 5**: (A): Polymict breccia found in the south eastern part of the crater rim at the coordinates: 22 49’28”N 40 49’25”E. (B): Polymict breccia found in the western part of the crater rim at the coordinates: 22 50’00”N 4042’30”E. (C): Polymict breccia found in the eastern part of the crater rim at the coordinates: 22 52’26”N 40 50’16”E. (D): Polymict breccia found in the western part of the crater rim at the coordinates: 22 50’00”N 4042’30”E. (E): Polymict breccia found in the western part of the crater rim at the coordinates: 22 50,42”N 40 42’18”E. (F): Polymict breccia found in the western part of the crater rim at the coordinates: 22 50’00”N 40 42’30”E

The age of impact was estimated by looking for basalt fragments within the polymict breccia, no basalt was found within the breccia implying that the impact occurred before the formation of the basalt from Harat Rahat which has been dated to the Neogene.

**Results**

The crater candidate described in this study is located in western Saudi Arabia, approximately 215 kilometers from Jeddah with the coordinates of 22°52'28"N 40° 46' 16"E. It lies on the eastern edge of Harrat Rahat.

It measures approximately 15 km in diameter. The crater rim height was relatively similar at different measuring points and was approximately 50-70 meters higher than the surrounding plains, as measured by satellite imagery.

The rim was almost entirely composed of impact breccia containing crystalline rocks (figure 5). Impact breccia was found in 5 different regions of the crater rim, with the farthest distance between two sample points being 15 km from each other. Ten grains of shocked quartz candidates were found upon microscopic examination of sand samples. Images in figure 4 demonstrate these findings.

**Discussion**

This paper describes the discovery of a previously unknown impact crater candidate in western Saudi Arabia. This may be the largest exposed and preserved impact crater reported in Saudi Arabia as of yet.

Several features of this crater resemble those of other craters found on earth. Like other confirmed terrestrial impact craters, this crater hosts impact breccia, quartz with planar features, and a circular crater rim.

The map created by the Saudi Geological survey indicates that this area contains conglomerate rocks, which includes breccia. This further confirms the nature of the breccia/rocks reported here. Due to the sheer amount of breccia and with this great distance, the chances of this breccia forming in traditional ways such as stream deposits and alluvial fan are greatly reduced, leaving the most probable cause of formation being extraterrestrial impact.

The impact breccia did not contain any fragments of basalt from Harrat Rahat which implies that the asteroid or comet impacted before Harrat Rahat's formation which puts the age of the crater to be >10 million years. No uranium-lead dating has been done to confirm the age of the crater due to lack of equipment but a rough estimate can be made. Due to the large amounts of erosion the crater has faced and the thick deposits of sand that has covered the center of the crater, it is estimated that the crater formed either during the proterozoic or paleozoic eras, and unlikely to have happened in the cenozoic.

The crater has a slightly oval shape(15.2km by 16.3km) meaning that there the impactor must have come at an angle, by estimating how oblong the crater is we can also estimate the angle of impact, giving a result of roughly 15 degrees. Impacts that happen at this angle create a small ricochet structure in the direction of the impact.

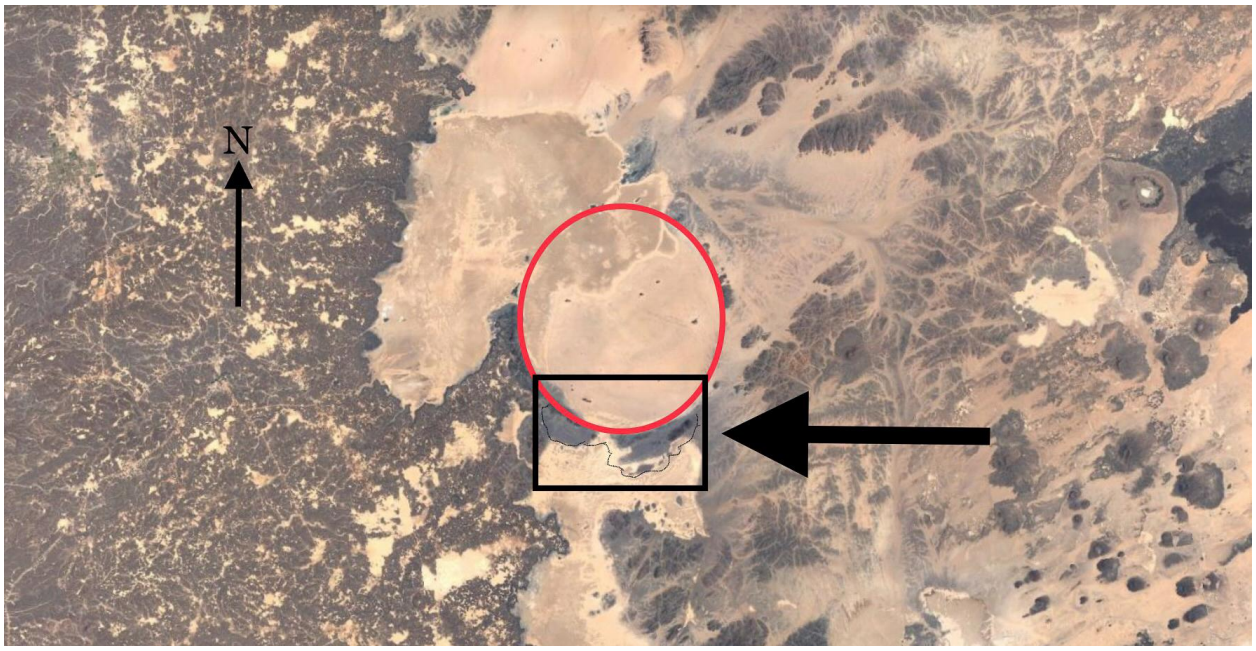


**Figure 6:** The potential small ricochet structure is present in the south of the crater(arrow) meaning that the impactor must have come from the north. An impactor coming from the north is unusual as it requires the celestial body to have a high inclination orbit. Most asteroids have low inclination orbits and do not hit at such a steep angle. Comets usually have high inclination orbits that do not conform to the ecliptic plane and therefore can impact earth from the northern direction at an angle of roughly 15 degrees. If proven using chemical analysis, this could be one of the very few preserved terrestrial impact craters caused by a comet. Chemical analysis of micro fragments of this comet within the breccia could provide significant data about its origin and history and further our understanding in the field (Elbeshausen, Dirk, Kai Wünnemann, and Gareth S. Collins, 2013).

2: 1-kilometer in diameter comet made of porous rock or ice traveling at 51 km/s which is the average speed of comet impacts (figure 7).


Your Inputs:

Projectile diameter: **1000.00 meters ( = 3280.00 feet )**
Projectile Density: **1000 kg/m$^3$**
Impact Velocity: **51.00 km per second ( = 31.70 miles per second )**
Impact Angle: **45 degrees**
Target Density: **2750 kg/m$^3$**
Target Type: Crystalline Rock

**Figures 7:** Figures 7 is a simulation conducted using the Impact Crater Map (Imperial College London) made by Gareth Collins, Robert Marcus, H.J Melosh.

If the impact happened in the Phanerozoic then it could be the cause of a minor regional extinction. Future research could be aimed at determining an accurate age of impact, determining the age of impact could find a correlation between a possible regional extinction event.

Regarding the naming of the impact crater, As the discoverer, I propose the name “Toonsi Crater” for further discussion and evaluation by the scientific community.

**References**

(French, Bevan M., and Christian Koeberl. “The Convincing Identification of Terrestrial Meteorite Impact Structures: What Works, What Doesn't, and Why.” *Earth-Science Reviews* 98, no. 1-2 (2010): 123–70. https://doi.org/10.1016/j.earscirev.2009.10.009).

(Elbeshausen, Dirk, Kai Wünnemann, and Gareth S. Collins. “The Transition from Circular to Elliptical Impact Craters.” *Journal of Geophysical Research: Planets* 118, no. 11 (2013): 2295–2309. https://doi.org/10.1002/2013je004477).