A Monograph
on
Ramgarh Meteorite Impact Crater
Rajasthan

August 2020

Indian National Trust for Art and Cultural Heritage

The Ramgarh Meteorite Impact Crater

Authored By

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And

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Japanese - Canadian Geographer/Artist


Ramgarh Meteorite Impact Crater
3D View
Ramgarh Crater
Shri Pura
Google Earth

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Sesquicentennial Celebration of Ramgarh Geoheritage Site -1869-2019

रामगढ़ भूधरोहरीय स्थल का अध्यर्धशतवर्षीय उत्सव - १८६९-२०१९

A comprehensive account of hitherto neglected natural wonder of India for furthering the global as well as national agenda. *"According to Geological Society of America **"Geoheritage"** is a generic but descriptive term applied to sites or areas of geologic features with significant scientific, educational, cultural, or aesthetic value. Such sites have high potential for scientific studies, for use as outdoor classrooms, enhancing public understanding of science, recreation, and economic support to local communities through tourism (Geotourism)"*

also

*"**Geodiversity:** It is a link between people, landscape, and their culture: it is variety of geological environment, phenomena and process that make those landscapes, rocks, minerals, fossils and soils which provide the framework for life on Earth-this cultural aspect, .reflects the important influence geodiversity has on society and culture."*

and

The Indian Union Governments policy of "advancement of the cause of geosciences by documentation, propagation, archiving, and education, including creation and management of geoheritage monuments and parks for use of the public, students, and researchers, and future generations. The purpose is to popularize geosciences for public".

Front Cover : Satellite view of Ramgarh Crater, Source: Esri

Frontispiece & Back Cover : A painting by the Japanese-Canadian geographer/artist Dr. Hiroshi Shimazaki (www.hiroshishimazaki.com), showing the imagined moment of impact of a meteorite at Ramgarh painted on a rare 'cratered' Dutch paper for the 150th Anniversary of the discovery of Ramgarh structure in 1869 by F. R. Mallet of Geological Survey of India

Team

Manu Bhatnagar, Principal Director, Natural Heritage Division

Collated by Dr. M. S. Sisodia and Dr. P. S. Ranawat of INTACH Udaipur Chapter

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Designed By Abhishek Kumar, INTACH

Shri Jitendra Kumar Sharma, Convenor, INTACH, Baran

Acknowledgments

India's neglected geoheritage needs dedicated champions and warriors and there is no dearth of these. Their specialized knowledge and dedicated enthusiasm combined with non-domain expertise and institutional support can get the sites greater visibility in the public domain and with decision makers.

Ramgarh meteorite impact crater is a prominent but overlooked geo-heritage. Seasoned geologists Dr. MS Sisodia and Dr. PS Ranawat pooled their efforts in writing this informative monograph. We acknowledge their stellar efforts and hope this monograph highlights the geological treasure.

As the site includes archaeological and natural assets and requires to be planned as a geo-tourism site [the core attraction being the crater itself] Abhishek Kumar of the Natural Heritage Division of INTACH has complemented the geologists essay with a schematic plan and recommendations to have planned tourism around the site. Along with the experts he has also organized and designed the layout of this monograph. We duly acknowledge his planning and design skills in this work.

Shri Jitendra Sharma, Convenor, Baran Chapter, INTACH, coordinated the site visits and provided local resources for the field work which are gratefully acknowledged.

Manu Bhatnagar
Principal Director
Natural Heritage Division
INTACH

Foreword

All countries have various unique geological and geomorphologic features which constitute their geoheritage. Over time, the development process obliterates many of these features and this loss necessitates the preservation of representative and/or spectacular features which explain the geological process over geological time or otherwise attract interest due to their magnificent visual characteristics.

Geoheritage has been a neglected feature in the conservation landscape of India. Geological Survey of India [GSI] identified 33 geological sites over the years as National Geological Monuments. Most of these are located in a few geologically rich states. Unfortunately, beyond declaration as geological monuments little else has been done to protect these marvels of the nature. Our earlier survey [2015-16] carried out for this report shows that most of the sites are lying forlorn and desolate and may well be lost to the country during the course of 'development'.

There is a crying need to identify stakeholders who will actively protect these sites, sensitize local administrations, tourism departments, and the public at large about this neglected heritage. Simple measures of protection, raising visibility and awareness, can make a significant difference.

In advanced countries as well as many developing countries the concept of geoheritage and geoparks has found much traction with sites being properly protected as part of larger bio-diverse landscapes and form part of tourism circuits. Many sites in China and even Vietnam have been notified as World Heritage Sites or Geoparks with UNESCO.

In India, there is little realization of the significance of our geological heritage outside academia and the geologist fraternity. There is a need to develop and conserve these geological identities recognizing and understanding the scientific value of the features and landforms. The tourism departments and tourism industry would also need to be made a major stakeholder to establish a fresh revenue stream, generate additional livelihood opportunities while preserving geoheritage, landscapes and associated biodiversity. The more spectacular the site the greater the tourism potential.

Thus, a major archaeological site such as Hampi is equally a rich geo-heritage site, an aspect which has been completely overlooked. Similarly, rock art sites in

Telangana such as Pandavulagutta [Warangal. district] have been overlooked as spectacular geological formations. Many river beds flowing through rocky terrain present riveting geological features.

Subsequently, it is anticipated that many more geoheritage sites will be identified and notified, thus affording these sites the necessary protection during the course of development. With serious effort some of these sites can make it to the UNESCO Geoparks network. It is hoped that this monograph will help to trigger work in that direction.

The Ramgarh site has natural features consisting of physiographic and biotic feature, which are of exceptional value from the aesthetic and scientific point of view, along with “cultural landscape” as enunciated by UNESCO -"...that includes cultural properties representing the combined works of man and the nature and is illustrative of the evolution of human settlement over a time, under the influence of the physical constraints and opportunities presented by their natural environment and of successive social, economic and cultural forces, both external and internal". Hence the Ramgarh Crater site represents a mixed natural and cultural attributes of great importance. Having identified these elements, the site should be promoted and developed to the international standard befitting a world heritage site that deserves membership of the UNESCO Geopark Network.

There is a long road ahead.

Manu Bhatnagar
Principal Director
Natural Heritage Division
INTACH

PREFACE

India is endowed with a rich range of abiotic natural elements, *viz.* rocks, minerals, fossils, landforms that greatly impacted our society and culture. One of the geodiversity aspects that evokes awe and amazement amongst its viewers is the sight of a noctilucent meteorite. Rarely, the larger cosmic bodies (a few km across) that survive the atmospheric blazing denudation fall on the surface of the earth, creating an impact crater at the site of its fall.

To the scientists, a meteorite provides an invaluable, rather a unique, sample of material of the earliest stages of the solar system history. Ramgarh Impact Crater Geoheritage Site is one such element that is eye pleasing geomorphic feature, which also has biotic, spiritual and archeologic heritage attributes. Located in a tropical area it has a forest that is protected by the environmental laws of the land and the commandments of spiritual faith of a *Dev-Vanee* (sacred grove). Though discovered as far back as in 1869 by F. R. Mallet of Geological Survey of India (GSI), this site could not get much needed impetus to be preserved, as a Geoheritage site.

Concerted efforts by INTACH, especially since November 2016, have resulted in the site gaining attention of the public and the administration. Through this monograph, the Natural Heritage Division of Indian National Trust for Art and Cultural Heritage [INTACH] brings out a distillate of the rich geosciences literature on impact craters and this 'God-sent' site, promoting the Union Government's policy of "…advancement of the cause of geosciences by documentation, propagation, archiving, and education, including creation and management of Monuments and Parks for use of the public, students, and researchers, and future generations. The purpose is to popularize geosciences for public…".

The Ramgarh Impact Crater site, fortunately, has natural features both physiographic and biotic, which are of exceptional value from the aesthetic and scientific point of view, together with "cultural landscape" as enunciated by UNESCO -"...that includes cultural properties representing the combined works of man and the nature and is illustrative of the evolution of human settlement over a time, under the influence of the physical constraints and opportunities presented by their natural environment and of successive social, economic and cultural forces, both external and internal".

It is pertinent to note that the Ramgarh Impact Crater site presents mixed natural and cultural attributes of a great significance. Having identified these elements, the site should be promoted and developed to the international standards befitting a world heritage site that deserves membership of the UNESCO Geopark Network.

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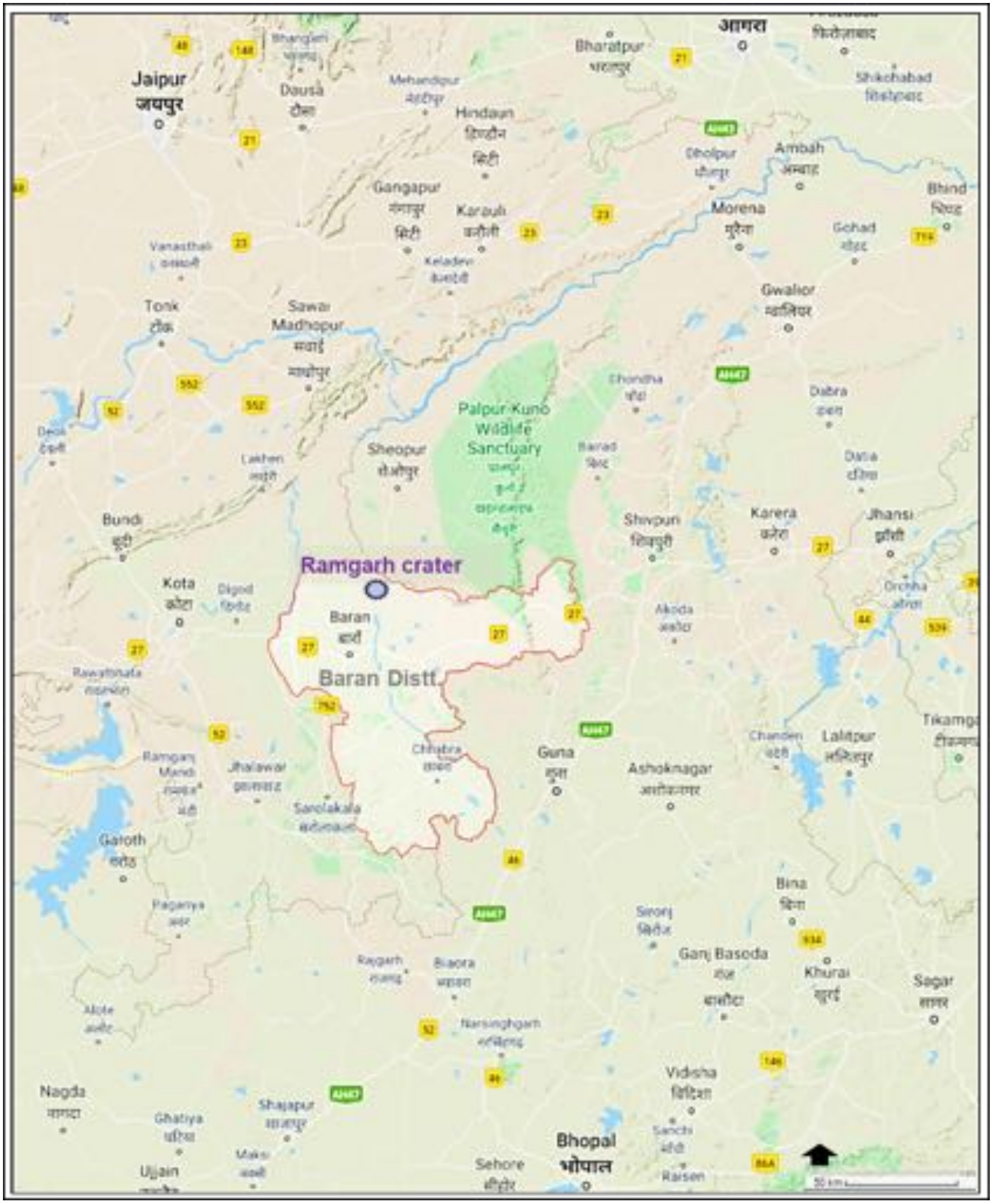


Map No 1 : Location Map of Ramgarh Crater

1. INTRODUCTION

"A **meteorite** is a solid piece of debris from an object that originates in outer space and survives its passage through the atmosphere to reach the surface of a planet or its moon(s). When the space debris is pulled by the Earth's gravity and enter the Earth's atmosphere, various factors such asram pressure (not friction), pressure, and chemical interactions with the atmospheric gases cause it to heat up and radiate that energy. It then becomes a meteor and forms a fireball, also known as a shooting star or a falling star. Meteorites vary greatly in size; astronomers call the brightest examples as 'bolides'. For the geologists, bolide is a meteorite large enough to create a crater". Most meteorites are stony meteorites (~86%), only about 6% of meteorites are metallic, iron-nickel meteorites, rest are a blend of rock and metal, the stony-iron meteorites. The sight of a fire-ball or noctilucent meteorite evokes awe and amazement amongst its viewers. To the scientists, a meteorite provides an invaluable, rather a unique, sample of the material of the earliest stages of the solar system history.

1.1 Meteorites-the Cosmic Samples

Shooting stars are common phenomena observed nearly every night. The wandering pieces of space debris enter the earth's atmosphere at an estimated speed of 15-72 km/sec, depending essentially on size and original path vis-à-visthat of the earth. Most of them burn out, due to aerodynamic heat, during their journey through the atmosphere (meteors). Consequently, space dust particles (micrometeorites) will 'float' to the ground; some of these could be identified and collected because they fell on snow! Rarely, we may be fortunate in getting a sample of the extra-terrestrial (ET) material, which may be a small grain (micrometeorite; cosmic or ET dust) or a large chunk-a meteorite. The largest reported intact meteorite, from Namibia, weighs nearly sixty tonnes and the second largest weighing thirty tonnes is also an iron meteorite brought from Greenland to New York. The heavier meteorites fall with a great speed and therefore generate an impact crater on the ground. Low-density ones (e.g. solidified gases) most likely formed some of the large craters on the surface of the earth. The June 30, 1908 explosion in Siberia (40 megaton atom bomb) may have been due to the explosion of a low-density cosmic material above the Tunguska River Valley ground.

The impact craters can unambiguously be confirmed by field and laboratory techniques. The shape of the crater and shock metamorphosed features, such as shatter cones, impact breccia, planar deformation features (PDF) and minerals like stishovite, maskelinite, ringwoodite *etc.* that are produced at the pressure of about 10 to 20gigapascals (GPa). Geochemical anomalies such as higher concentration of platinum group elements, noble gases or isotopic anomalies are also confirmatory evidences for the impact craters.

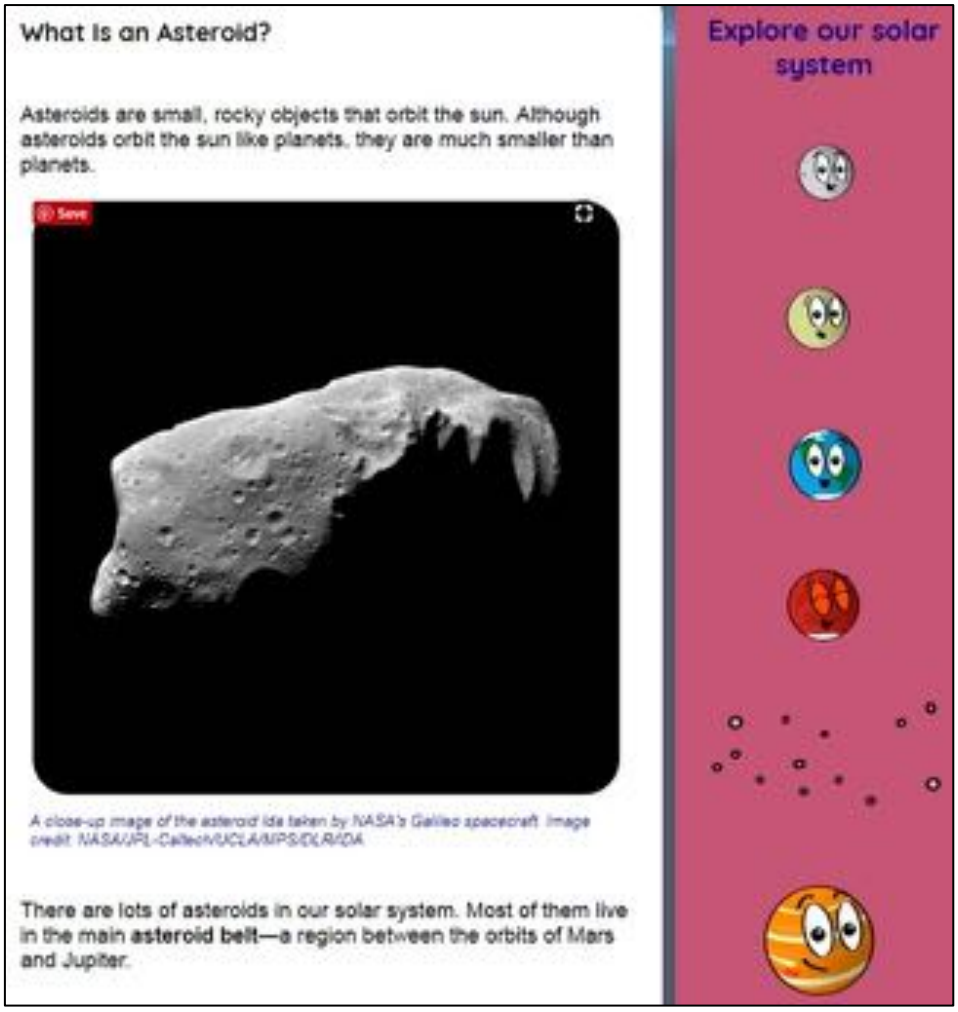


Figure No. 1 : Details about asteroids

Source : World Wide Web

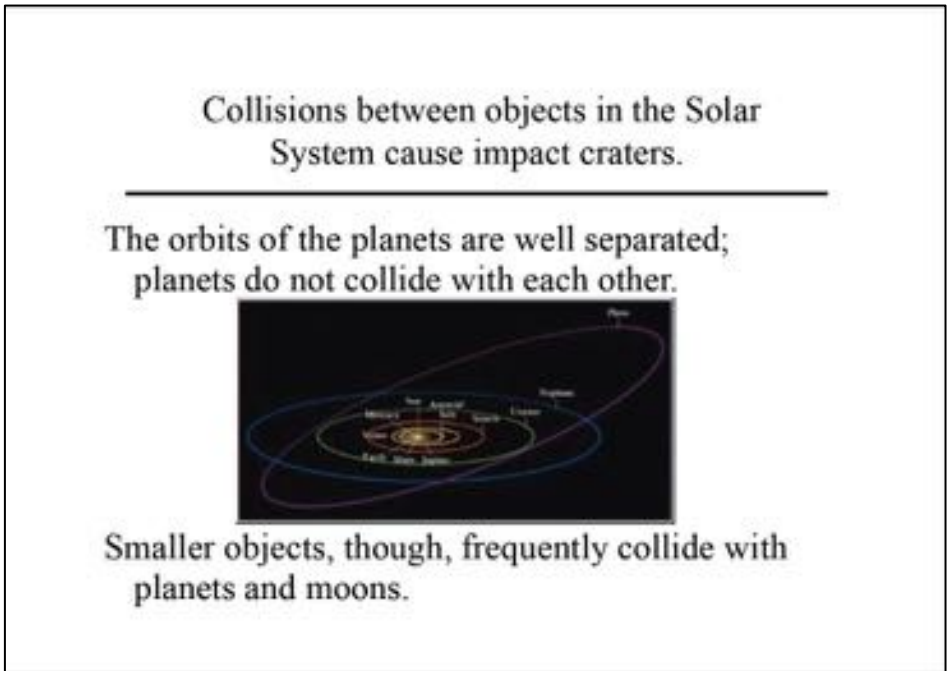


Figure No. 2 : Orbital Structure of Planets

Source : World Wide Web

The Prehistoric Iron

It is now well established that humans first used stone tools (lithic, image below) followed by those of native metals; -gold was too soft and rare, while copper was also not all that hard, the problem was partly solved by alloying copper with tin to make a somewhat harder alloy-bronze (2000 BCE-500 BCE), there after human invented technique to smelt iron from its oxide ores (500 BCE), to usher in the IRON AGE. But there are rare iron implements of prehistoric times. Iron daggers, axe, head-rest... of the Bronze age have been found in Syria, Turkey, and Egypt. The most famous example is the iron dagger found in 1925 with the mummy of Egyptian Pharaoh Tutankhamen (1350 BCE). The French archaeologist Albert Jambo (2017) using the non-destructive technique of x-ray fluorescence (XRF) proved that these implement contained 11 percent nickel and traces of cobalt, a composition characteristic of extra-terrestrial iron found in many iron meteorite. Likewise, Danish archaeologists found evidence that early Eskimo hunters broke iron from giant meteorites on the Greenland ice sheet using basalt stones. A meteorite broke apart and fell onto the ice sheet around 10,000 years ago; the iron it contained was used to make knives and harpoons for centuries. Iron from the Greenland meteorite has been found as far away as Canada. Scientists say that the huge chunks of meteorite kick started Greenland's Iron Age long before Norse settlers brought iron ore to the island. So if you come across a pre-historic iron sword or an iron implement in your area, you have a treasure indeed from the space.

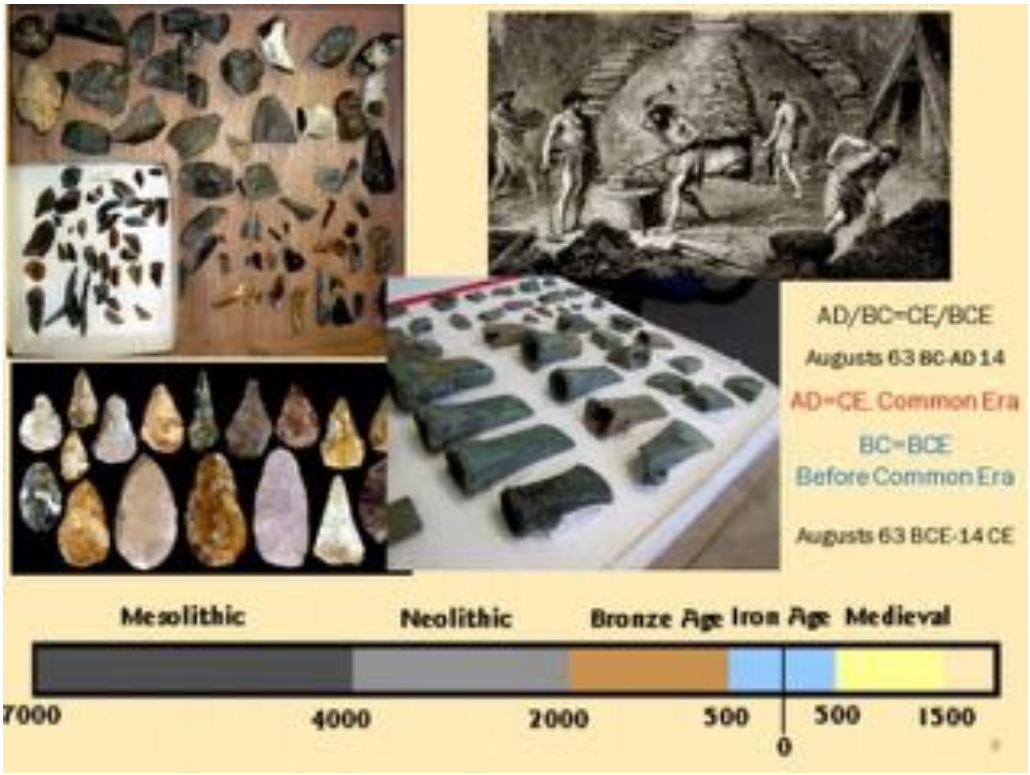


Figure No. 3 : The Prehistoric Stone and Metal Implements

Source : World Wide Web

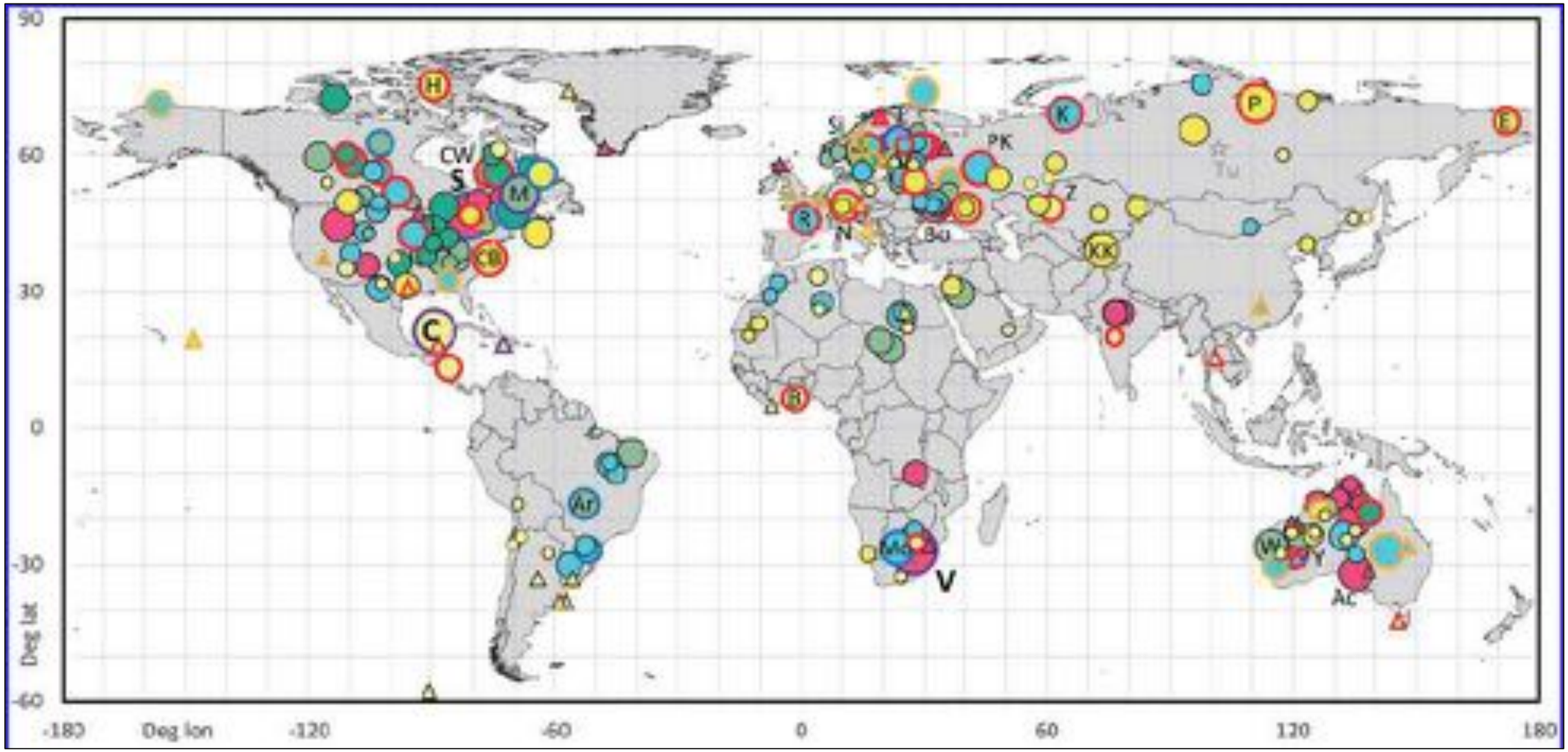
Figure No. 4 : The 1350 BCE Iron Daggers of Tut

Source : World Wide Web

1.2 Major Meteorite Impact Craters of the World

Impact cratering is a fundamental process operating on all the celestial bodies of the Universe including the Earth. It is one of the primary mechanisms responsible for planetary accretions to shaping the planetary surfaces. The Earth, similar to other planets, has continuously being hit by small and big extra-terrestrial bodies since its formation, but the dynamic processes operating on the Earth have mostly obliterated the impact signatures. The tectonics processes and erosion, in contrast to the Earth, are not extensive on other planets and satellites hence the morphology of impact generated craters, their sharply circular pits, widespread ejecta deposits, impact melt flows and the terraces and cliffs formed during crater development have been preserved.

The Earth Impact Database (2020) shows details of only 200 confirmed terrestrial impact craters on our planet (Schmeider and Kring, 2020). The Vredefort crater in South Africa is the biggest crater in the world; it has a diameter of about 300 km. A little smaller to Vredefort is Sudbury crater in Canada, which has an estimated diameter of 130 km, it is famous for its nickel deposit.



Map No 2 : showing confirmed terrestrial impact craters in the world, note three confirmed craters in India viz., Lonar, Maharashtra; Dhala, Madhya Pradesh; and Ramgarh, Rajasthan.

Source : After Schmeider and Kring, 2020

The most famous of them is the **Chicxulub Crater** of Yucatán Peninsula in Mexico. It was formed by a large asteroid or comet about 11 to 81 km in diameter striking the Earth. The crater is estimated to be 150 km in diameter and 20 km in depth. It is the second largest confirmed impact structure on Earth and the only one whose peak ring is intact and directly accessible for scientific research. The date of the impact coincides precisely with the Cretaceous–Paleogene boundary (K–Pg Boundary or K/T Boundary), dated at 66 million years ago, which coincides with the view that the worldwide climate disruption from the event was the cause of the K-Pg (K/T) extinction event, a mass extinction in which 75% of plant and animal species on Earth became extinct, including all non-avian dinosaurs.

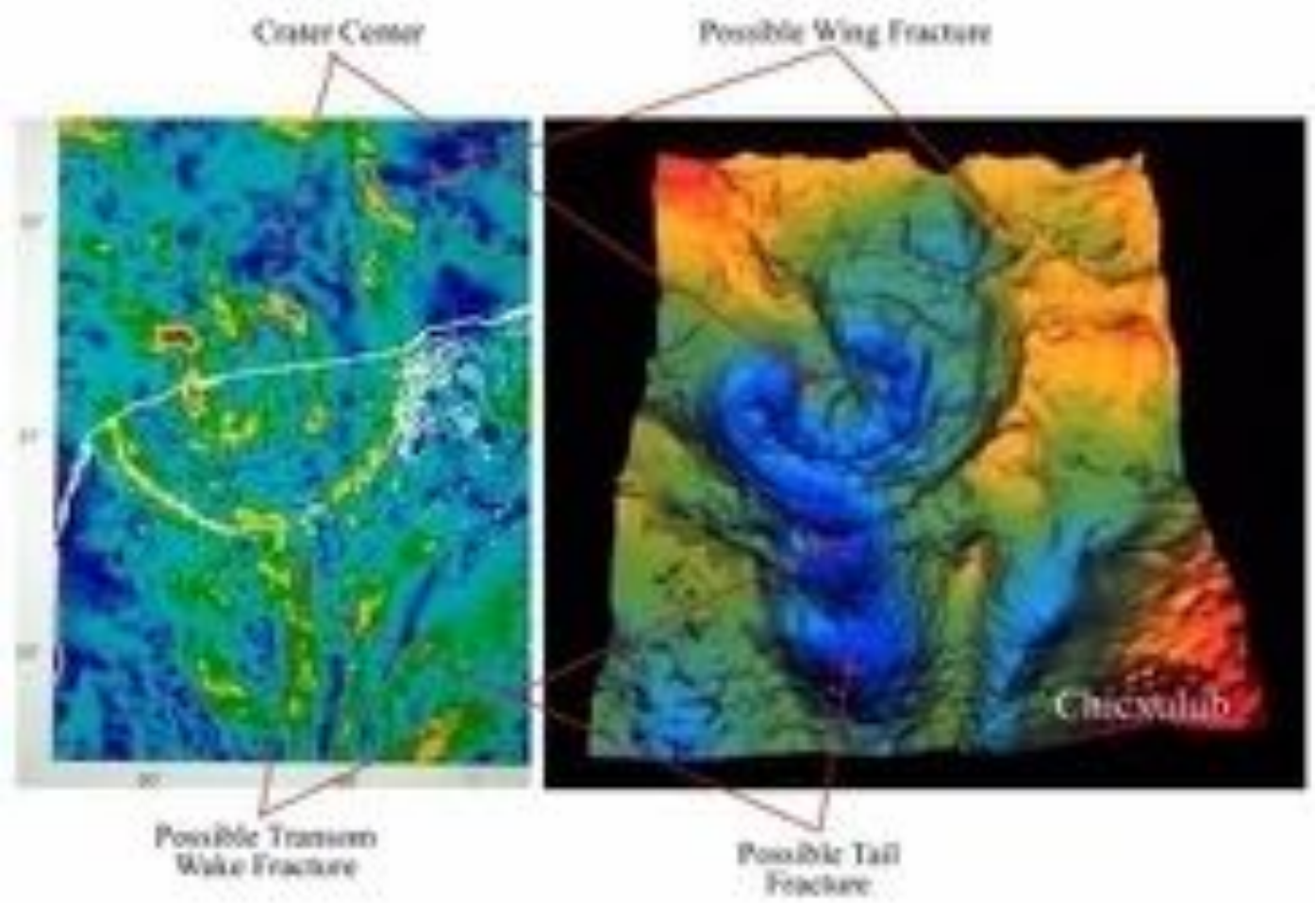


Figure No. 5 : The Chicxulub Crater of Yucatán Peninsula in Mexico

Source : World Wide Web

Another world-renowned Meteor Crater**, the first to have been identified as an impact crater on the Earth's surface,** also called **Barringer Meteorite Crater** or **Arizona Meteor Crater**, was produced by a large meteorite in the rolling plain of the Arizona, U.S. The crater is 1,200 m in diameter and about 180 m deep inside its rim, which rises nearly 60 m above the plain. Drillings reveal undisturbed rock beneath 213–244 m of fill. The strata forming the rim of the crater are upturned and covered with the debris of the same bedrock, which

shows an inverted stratigraphy. NASA used it for training of its would-be astronauts for the Apollo Mission[1].

Figure No. 6 : View of Arizona Crater

National Meteorite Repository, Geological Survey of India[2]

Meteorites, the extra-terrestrial rock pieces, arrive from parts of the solar system packed with wealth of information on the creation of our mother earth and the solar system as well. Since inception of the Geological Survey of India in 1851, Thomas Oldham, the founder Director, took interest in collection of meteorites from private collectors and displayed in the gallery of Indian Museum in Calcutta. He also started systematic cataloguing the meteorites. **GSI is the authorized curator and repository of all the meteorites fall on the Indian soil and presently possesses about 700 meteorites of different kinds.**

Geological Survey of India has been the sole custodian for all meteorite "falls" or "finds" within Indian Territory and it has conserved the Indian meteorites for scientific researches as well as for posterity. Each milligram of meteorite sample is invaluable, as the answer to the very question of "our origin" perhaps lies within such meteorites. Every meteorite is, to a great extent, unique in its own way and demands extreme urgency and awareness in matters of collection and proper preservation.

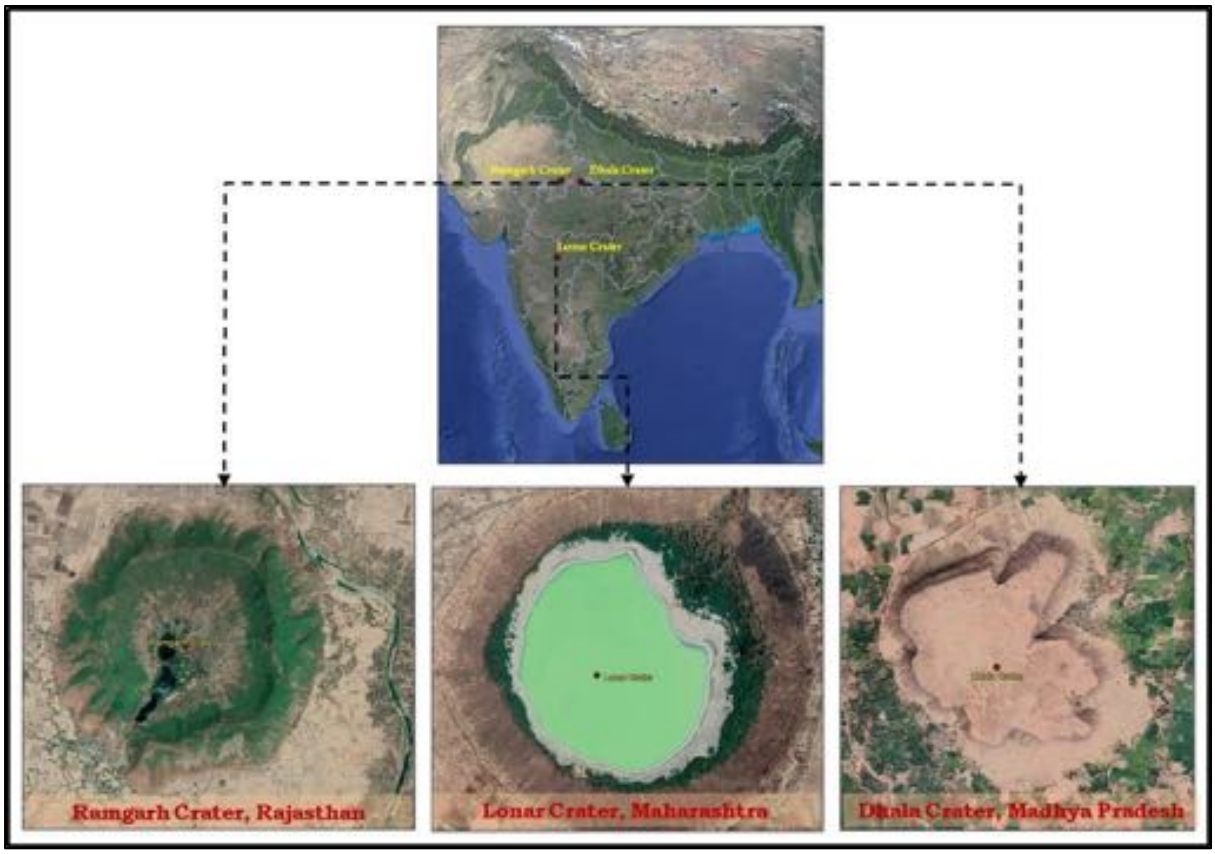
The museum exhibits 105 number of different kinds of meteorites of Indian origin as well as 384 number of unique meteorites collected from all over the world. They are well preserved in the Meteorite Repository of Geological Survey of India and are an invaluable asset of our country.

[1]- https://www.britannica.com/place/Meteor-Crater

[2]**http://museum.gsi.gov.in/cs/VirtualMuseum/page/meteorite**

2. MAJOR METEORITE IMPACT CRATERS OF INDIA

The impact record of India consists of only three confirmed impact craters, *viz*., Lonar in Maharashtra, Dhala in M.P., and Ramgarh in Rajasthan



Map No 3 : Key Map of India Showing Location of 3 Confirmed Terrestrial Meteorite Impact Craters

2.1 Lonar Crater

Lonar Crater (लोणार)(N19°58'36": E76°30'30") is one of the three confirmed meteorite impact craters in India[3]. Additionally, it is a declared National Geological Monument by Government of India through the Geological Survey of India under the category "**Geological Marvels".**

It is nearly circular, bowl-shaped crater, located in Buldhana district of Maharashtra in the extensive Deccan Volcanic Province (DVP). Measuring 2.0 km from rim to rim, the crater is partially filled by a salty, alkaline lake (लोणार सरोवर) 1,200 meters in diameter and is about 137 m below the crater rim. Geologists, ecologists, archaeologists, naturalists and astronomers have reported several studies on the various aspects of this Crater Lake ecosystem. Early investigators of this unique geomorphic feature ascribed its origin to

[3]cf. Earth Impact Database-EID, Canada
http://passc.net/EarthImpactDatabase/New%20website_05-2018/Index.html

some form of explosion or subsidence. Although developed in the Deccan flood basalts, the crater cannot be genetically related to these traps, which were extruded during the Cretaceous period (145.5 to 65.5 million years ago mya). The youthfulness of this structure indicates its origin long after the cessation of Deccan volcanic activity. Recent researches have tended to support the view that the Lonar structure is a hypervelocity impact crater of Quaternary age (2.588 mya). This view is borne by the high degree of circularity, the depth to diameter ratio, the thick layers of breccias constituting the rim and overlying paleosols (soil of past age), the quaquaversal dip (dipping from a centre toward all points of the compass)of the surrounding country rock, and the mounds of impact debris (impactite) lying around the crater rim. The regional dip is zero. The crater wall dips between 5° and 25°, with overturn observed in the rim fold.

The large variation in estimated age of the crater ranging from some 13,000 years to about 52,000 years adds to uncertainties surrounding the age of impact and demands further investigations.

Lonar Crater is an excellent site for studies of impact crater formation and deformation, shock magnetization, and fluidized ejecta.

Image No. 1 : Google Satellite Image of the Lonar Meteorite Crater of Maharashtra

-An NGM under "Geological Marvels" Category Declared by GSI. GoI

Image No. 2 : The Lonar Lake From the Rim of the Crater

2.2 Dhala Crater

Dhala Crater **(ढ़ला)**(N25°17'59.7": E78°8'3.1") is a crater formed by an asteroid impact. It is situated in Shivpuri district, Madhya Pradesh, India and is the second such crater found in India, after Lonar Lake. The diameter of the structure is estimated at 11km and basement rocks are predominantly composed of granitoids. It is estimated that the impact occurred about 2,500 mya [million years ago]. Dhala Crater is considered as the largest in India as well as between the Mediterranean and Southeast Asia. The crater is considered a "large complex impact structure" with an estimated diameter extending up to 11 km.

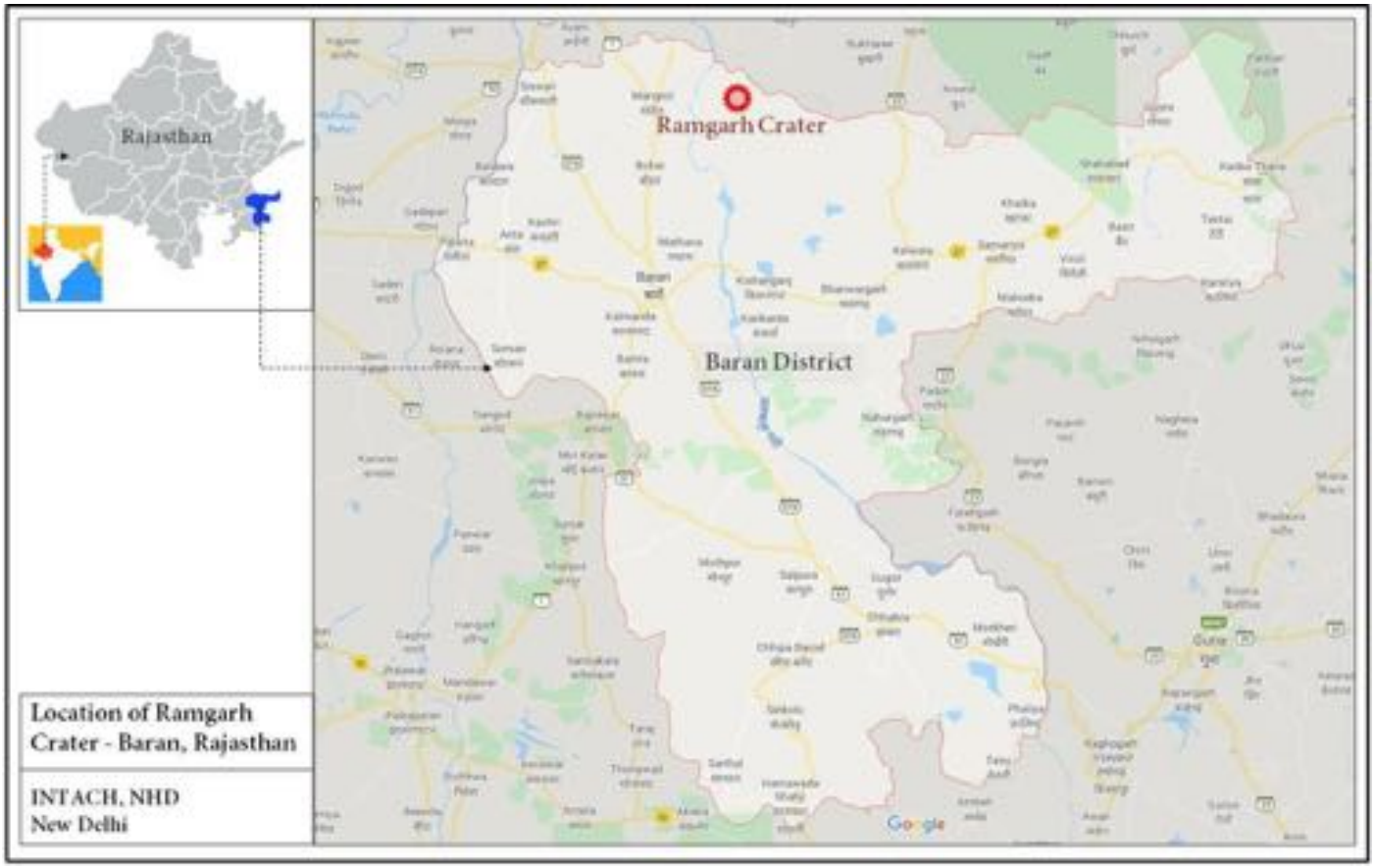
Image No. 3 : Dhala Asteroid Impact Crater is the Largest Impact Crater Between Mediterranean and SE Asia

It is mostly covered with soil of ~2500 old? rocks but has ~1700 million year old rock deposited in it, which proves that this structure is more than 1700 million years old Impact Crater

2 RAMGARH METEORITE IMPACT CRATER– A Neglected Natural Heritage Site

3.1 Introduction and Location

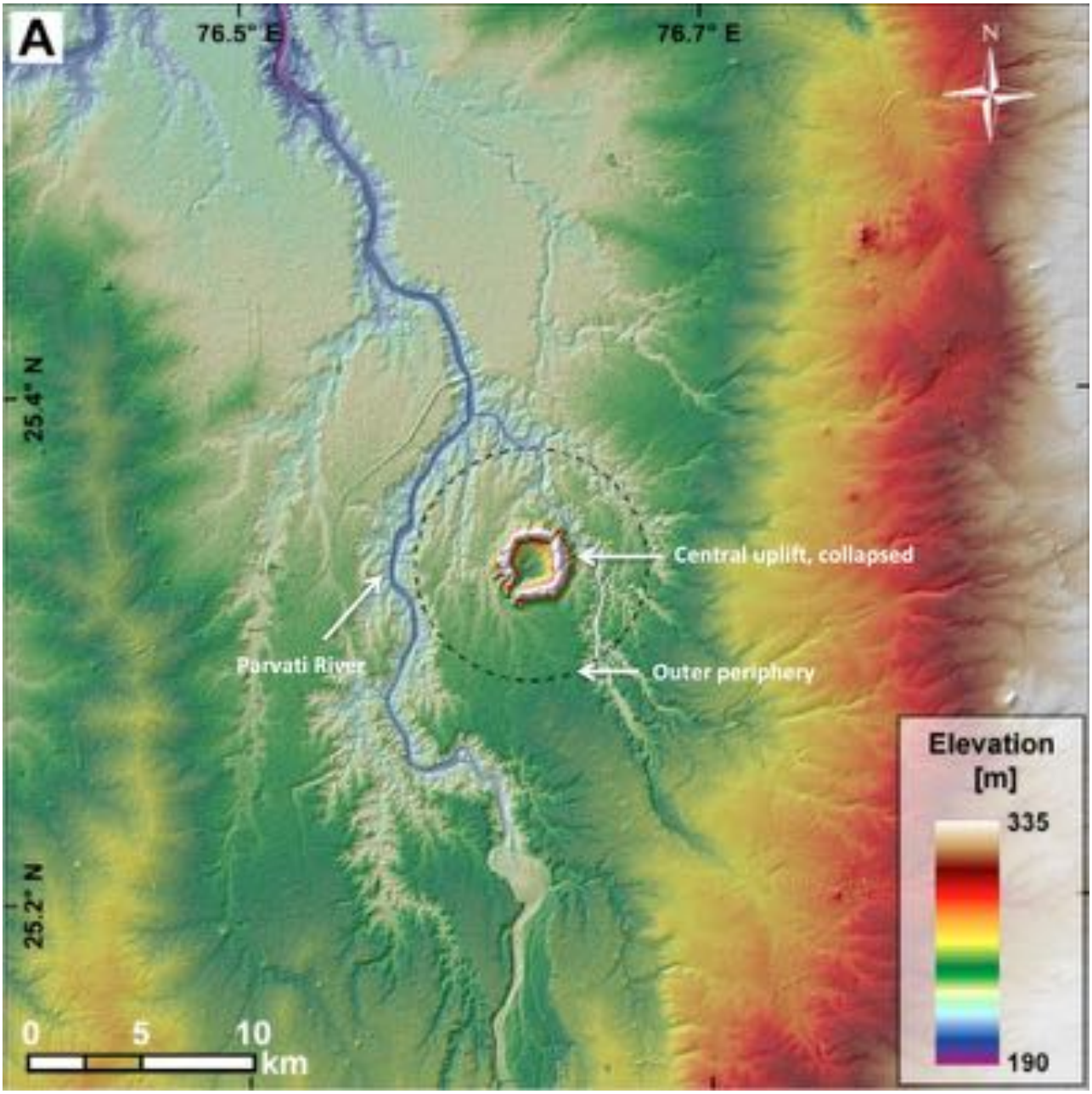
The Ramgarh (pronounced Ramgadh, रामगढ़) Impact Crater is located in the Baran District in southeast Rajasthan, India (25°20′N, 76°37′E), about 110 km northeast of Kota city. It is excavated in sandstone and shale and also minor limestone horizons of the Bhander Group of Vindhyan Supergroup. The moderately oblique impact occurred into a shallow water regime on the horizontally lying 1000-1070 million years old, Upper Vindhyan sedimentary rocks. The impact is supposed to have occurred during middle or upper Jurassic period, about 165 million years ago.



Map No 4 : Location Map of Ramgarh Crater

The Ramgarh Impact Crater is a complex impact crater of about 10 km diameter that has a collapsed Central Uplift. The collapse has caused a central depression while its rim rises prominently ~ 200 - 250 m above the surrounding plain as a continuous ring that has an approximate diameter of ~ 3.5 and 4 km in the east-west and the north-south directions respectively. It is actually this rim of the collapsed Central Uplift that is visible in the imageries or in the field. The periphery, see dotted line in the map that follows, of the Impact Crater has either been completely eroded or is submerged under the sediments. The crater falls in Survey of India topo-sheet 54 C/11. It is smaller in size than11km diameter

Dhala Impact Crater (Shivpuri District, MP) but larger than 1.8 km Lonar Meteorite Crater of Buldhana District, Maharashtra. This unusual rocky landform remained enigmatic for many years for the geologists since its discovery in 1869. It is only recently, that is in the year 2019, it is conformed as an impact crater. The Ramgarh Impact Crater is known by many other names too, *viz.,* 'Ramgarh structure', 'Ramgarh meteoritic structure', 'Ramgarh ring structure', 'Ramgarh dome', 'Ramgarh dome structure', 'Ramgarh astrobleme'.



Map No 5 : Imagery showing wider region of the Ramgarh Impact Crater and surrounding area with elevation data. Note the collapsed Central uplift and the margin of the complete crater

Source : After Kenkmann *et al.*, 2020

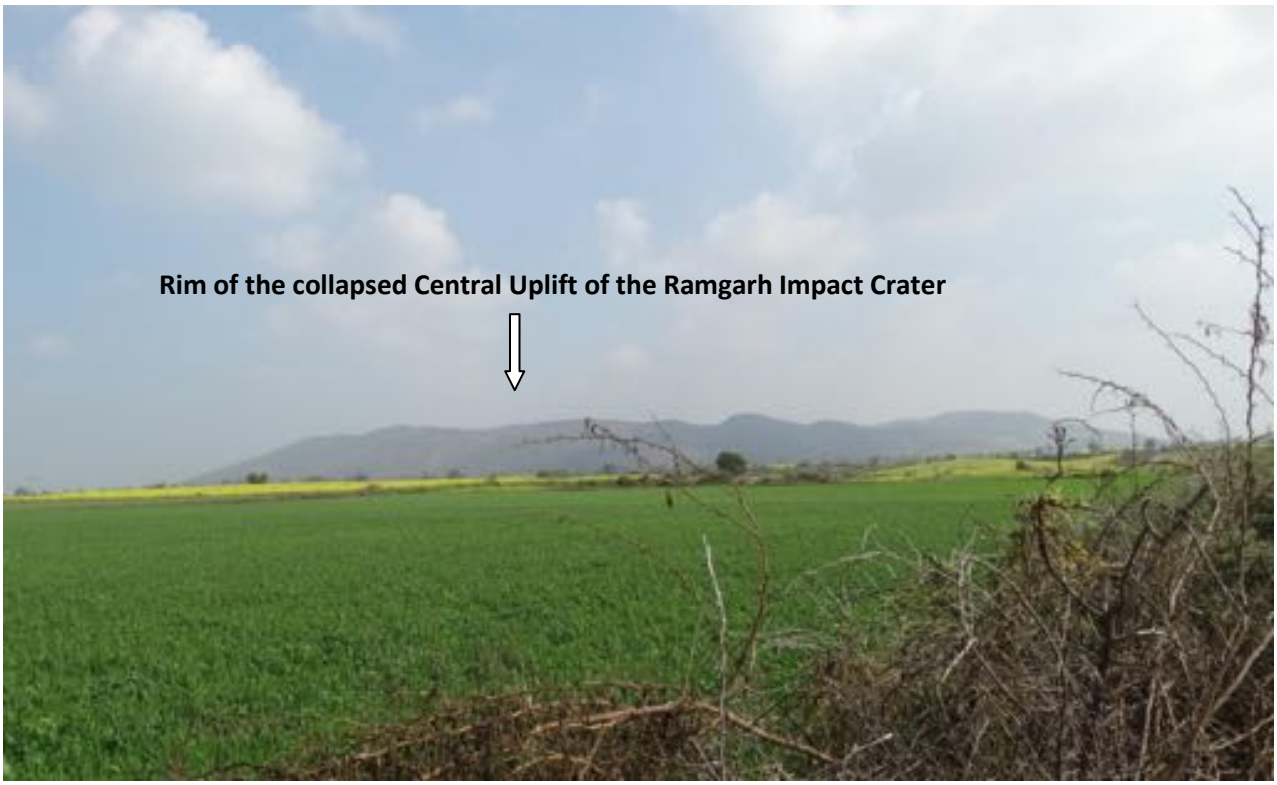
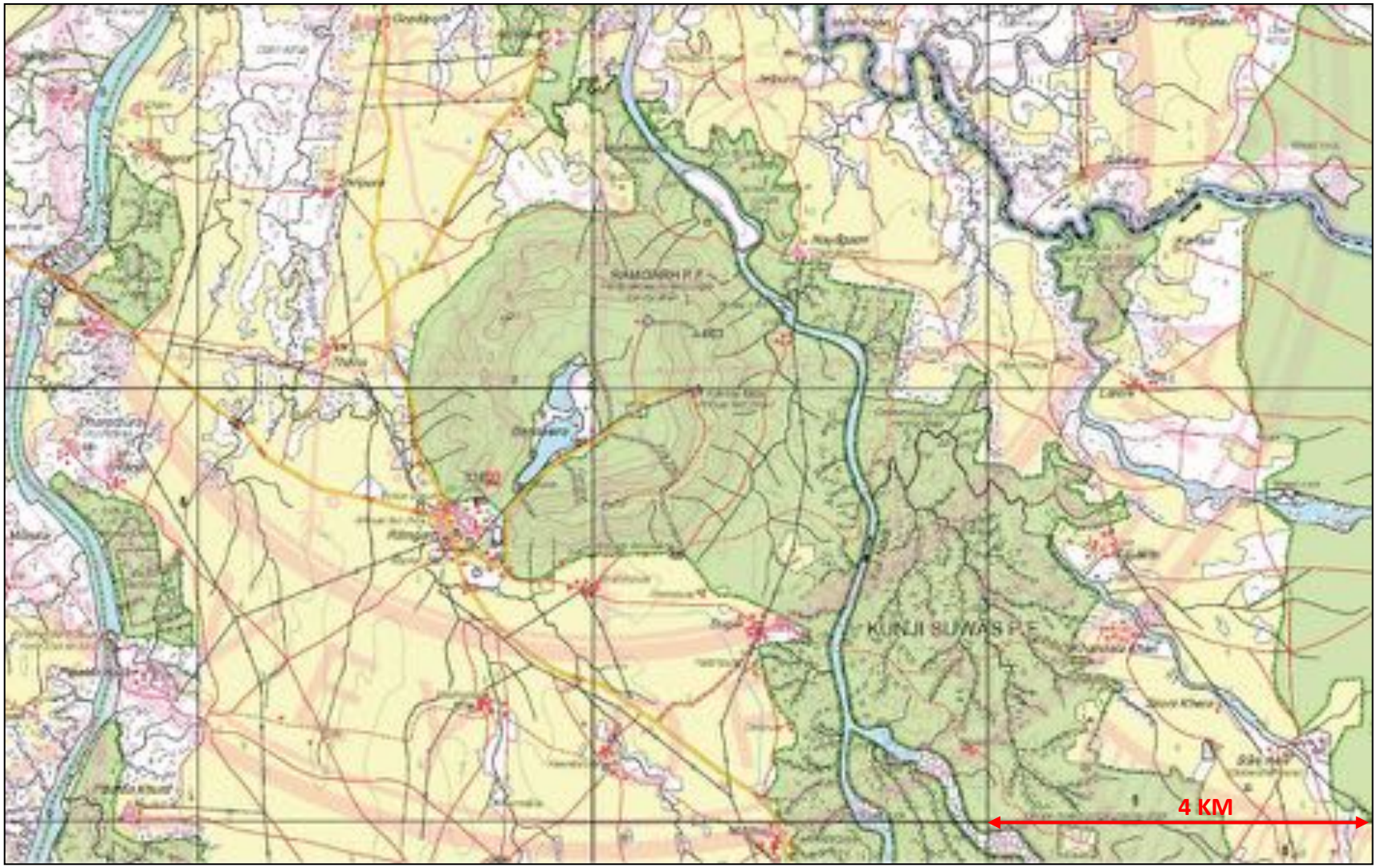


Image No. 4 : External View of the Rim of the collapsed Central Uplift [from south-west]

Image No. 5 : View of the central depression at the entrance [looking south]



Map No 6 : Ramgarh Impact Crater on Sol Map, Marked as Protected Forest

(Source: Survey of India, Surveyed in 1968-69, Updated in 2005-06)

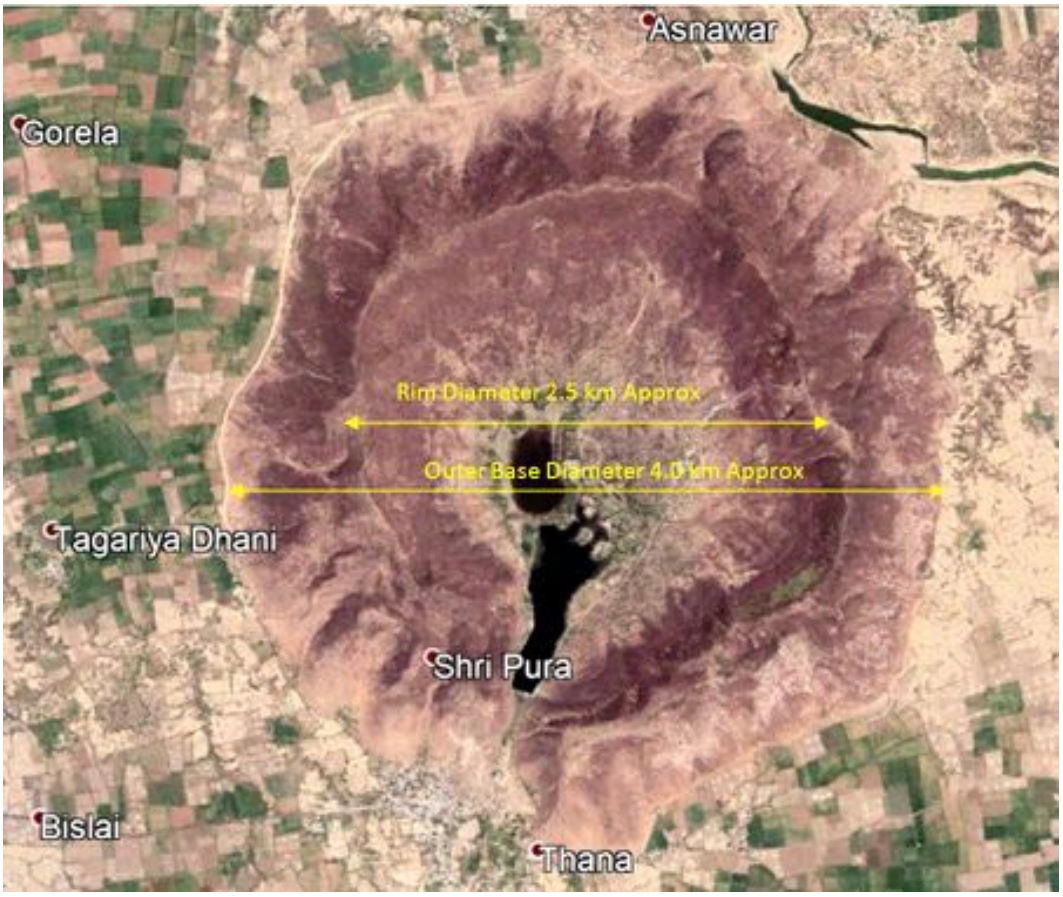


Image No. 6 : Google Satellite Image of the collapsed Central uplift of the Ramgarh Meteorite Crater, SE Rajasthan

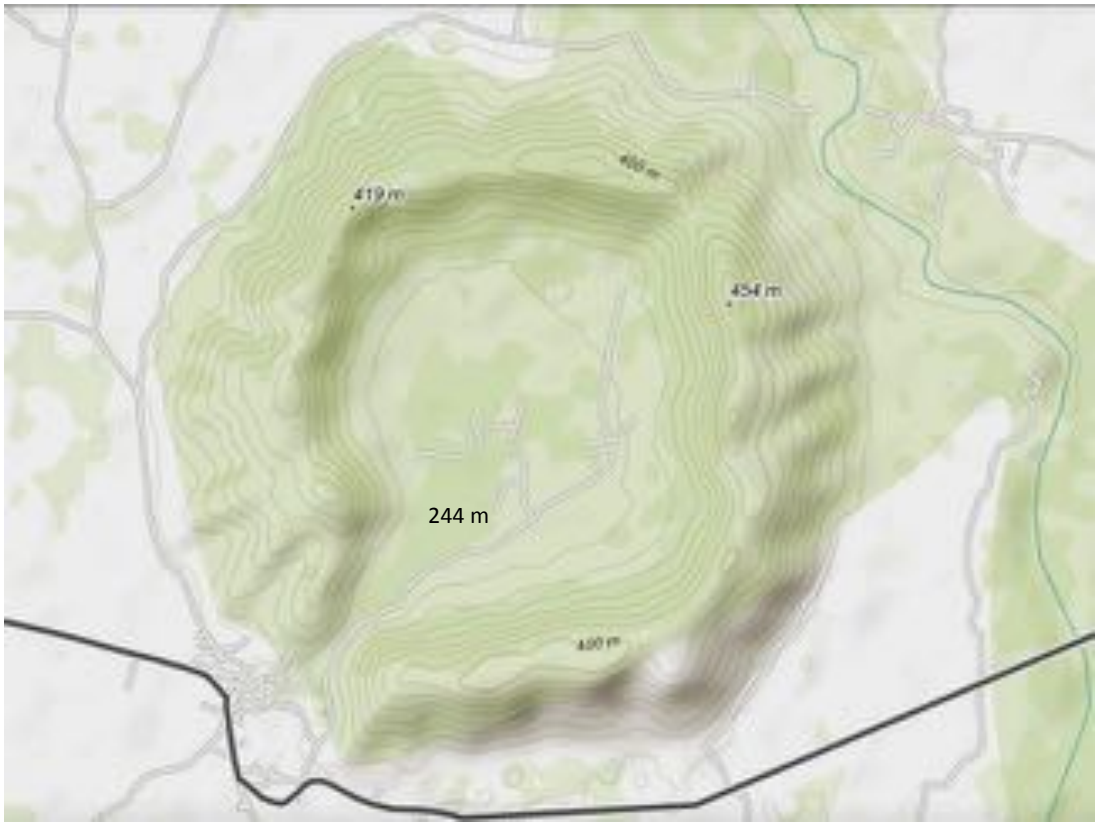


Image No. 7 : Contours and Level of Ramgarh Crater Uplift

3.2 Discovery

In 1869 F.R. Mallet of the Geological Survey of India was the first to record its existence, thereafter it was geologically mapped in 1882-83, and its geophysical survey was done in 1969-70, followed by photogeological investigation in 1973. Thereafter, GSI as well as academicians studied it in detail through investigative field studies and advanced laboratory investigations. Research publications of M. S. Sisodia et al (2006), S. Mishra et al (2018), and Kenkmann et al (2020) provided clinching evidence of meteorite impact that confirms Ramgarh crater as a meteorite impact crater.

3.3 Geology of Ramgarh Structure

Ramgarh Impact Crater is formed in the flat lying sedimentary rock terrain and is situated in the centre of the Vindhyan Basin of the Bundelkhand Craton of Proterozoic age. The collapsed Central Uplift of the crater shows Upper Rewa Sandstone of the Upper Vindhyan Group of Proterozoic age exposed at its geographic centre and shows vertical dips.

The central depression comprises heavily deformed shales, sandstones and limestones, which are partly disintegrated into fault-bounded mega blocks belonging to younger Ganurgarh Shale Formation. Lower Bhander Sandstone of the Upper Vindhyan Group is exposed at the neck of the dome. The sandstone exposed around the rim of the collapsed Central uplift has dips between 45˚ to 78˚, gradually flattening down to 20˚ to 30˚ at outer slope, and to 5˚ to 15˚ at the foot of this structure. The rim of the structure is discontinuous only at the southwest and is displaced by a set of NE-SW dextral strike slip faults.The cross-cutting relationships of this fault along with other two faults trending N-S and E-W suggest that these faults post-date the impact. The fault breccias associated with these faults consist of mm-sized angular fragments of sandstone within deep brown colour fine-grained matrix.

The Ramgarh Impact Crater as compared to Meteor Crater in Arizona, U.S.A. or Lonar Crater, Maharashtra, India is in a more degraded state. The other comparable terrestrial asteroid impact craters on sedimentary target-rocks of equivalent diameter are: B. P. structure, Libya (25°19′N, 24°20′E); Goyder Crater, northern Australia (13°9′S, 135°2′E), and Gusev Crater, Russia (48°26′N, 40°32′E), see Earth Impact database (http://www.unb.ca/passc/ImpactDatabase) or a paper of 2020 by Schmeider and Kring. Most importantly, Ramgarh Impact Crater is very special in the sense that it reveals an impact on a water-submerged target and therefore has a huge scope for the researchers who study Impact Cratering. **It is the sole crater till date that shows an impact in a water filled regime.** Different opinions were proposed for its origin but it has been proved now that it was formed due to asteroidal impact on the basis of following observations: impact spherules, diaplectic glasses, specific crater morphology, brecciation, multiple striated joint surfaces, swinging strike, radial folds, deformed central uplift particularly in the absence of any igneous activity, planar fractures along crystallographic planes, irregular extinction and mosaicism, toasted quartz, isotropic grains and patches as well as planar deformation features (PDFs) and decorated PDFs with occasional ghost traces of original PDFs, accretionary lapilli, high Ni content and also anomalous Cr and Co.

A small river, located in the SW opening of the hill, forms part of the drainage of south to north flowing ***Paarvati*** River located 4 km in the west. A number of small rills and gullies with radial/centripetal drainage towards the centre are developed in the area.

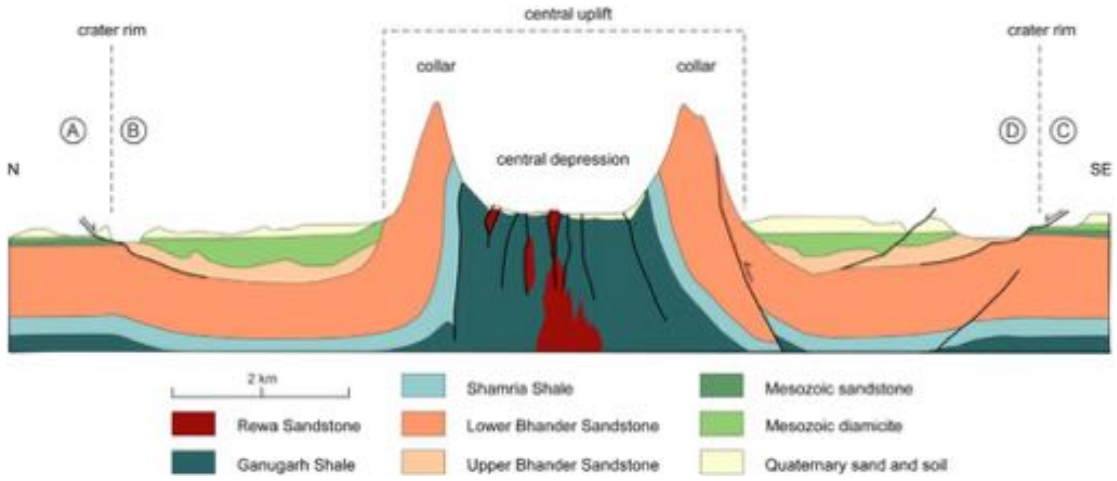


Figure No. 7 : Schematic cross-section showing Geology through the Ramgarh Impact Crater. After Kenkmann et al., 2020.

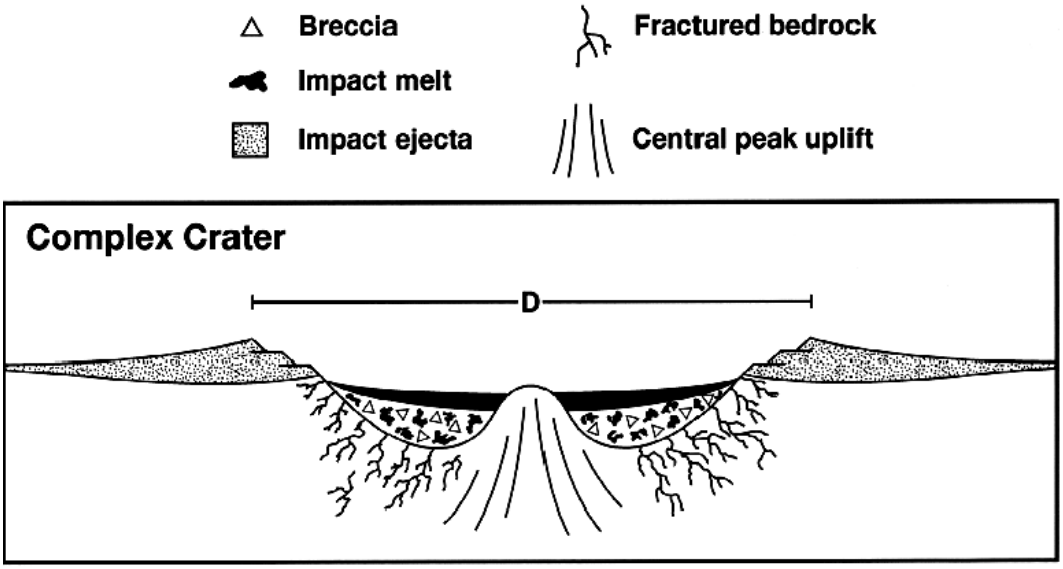


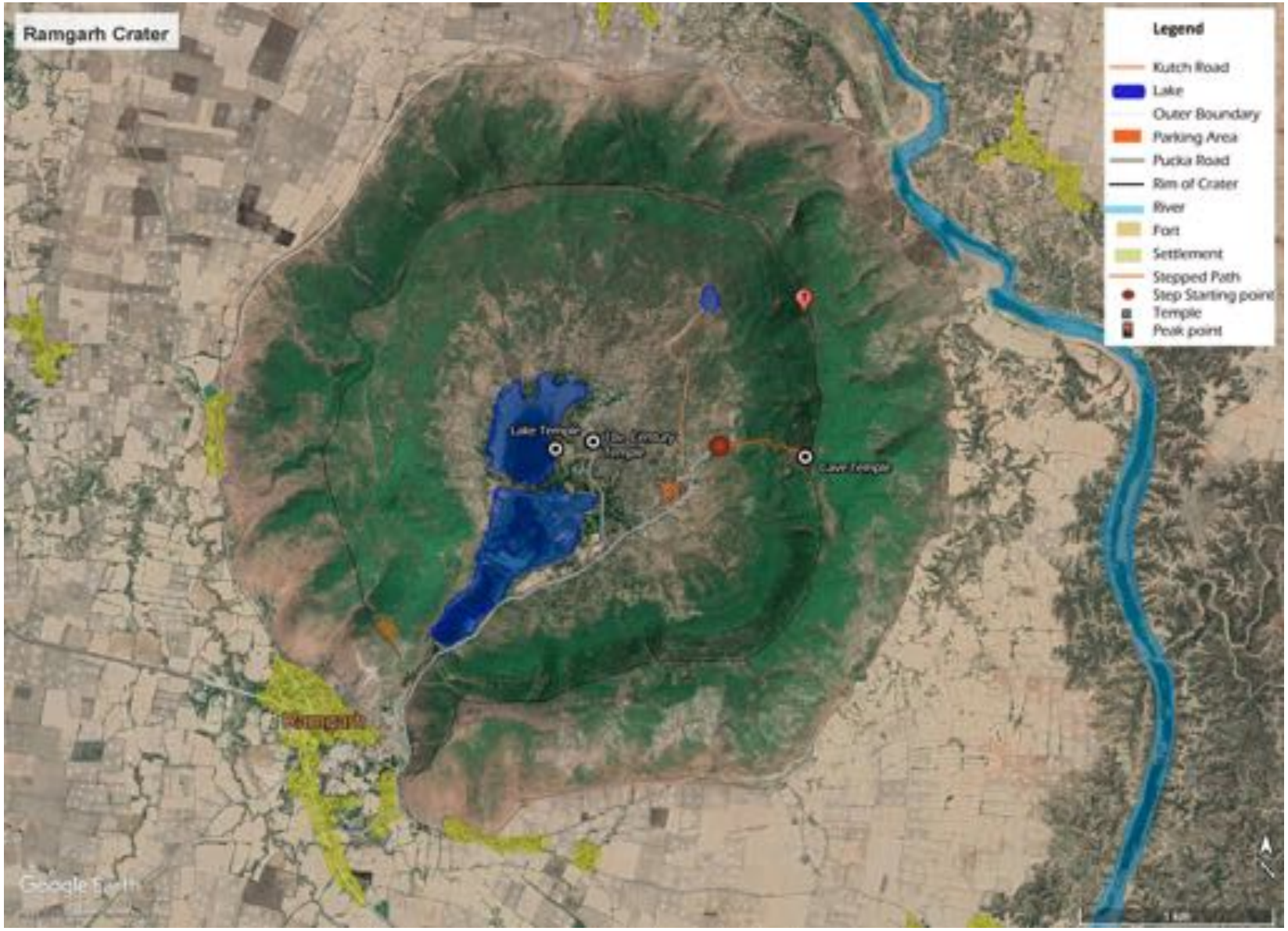
Figure No. 8 : I Idealized Section Across a Complex Meteorite Impact Crater With Central Uplift

3.4 The Crater As a Mixed Heritage Site

The Ramgarh Meteorite Crater has better drainage outlets (compared to Lonar Crater) and has seen thriving human habitation as evidenced by ruins of a fort (*Ramgadh Kila*?) and its ramparts, palaces, houses, huts and temples, which are under the protection of the Department of Archaeology& Museums, Government of Rajasthan (Kota Range).

This exotic landform that was well utilized by humans up to the medieval period but in disuse thereafter, needs to be promoted as a **National Geoheritage Site**, **because it has geologic as well as archeologic, spiritual elements that would be of interest to domestic as well as foreign tourists.**

The crater is 30 km from Baran, a narrow metalled road bypassing Thana village approaches the site. The rim of the collapsed Central Uplift dips very low to the south and the road enters the otherwise high rising rim at this point. Before entering the rim of the collapsed Central uplift, ruins of a fort are visible on the crest [rim] to the west. Upon entering the central depression, the lotus-filled fresh water lake sprawls in front; the lake is locally called *Pushkar Jheel*. This 1300m long lake collects the surface and subsurface runoff [from 900mm annual rainfall] and plays host to migratory birds in winter. A notable site is the Shiv temple (Bhagn-Devra from भग्न-देवालय for the damaged temple) built in tenth century akin to Khajuraho style. The decapitated remains of this temple reveal that it was a magnificent spiritual site during its glorious past. This temple is dedicated to the "Tantric tradition of Shaivism". In the *Garbh Griha* or sanctum of the temple is a Shiv Lingam (but it seems this lingam is not the original, the original sculpture of the deity must have been destroyed). There are ornately carved pillars depicting erotica, music, dance, *ashtadikpalas*, *saptamatrikas*, *Ganesh, Vishnu avatars etc.,* surprisingly it also shows sculptures of Shiv in the form of "Bhairav". The State Department of Archaeology and Museums have put a sign-board that reads: "The inscriptions found on the site indicate that the temple was built in the 10th century CE by Raja Malaya Verma of Nag Dynasty from Malwa, and was renovated in 1162 CE by Raja Trisna Verma of the Med Dynasty". There is also information that the *Bhand-Devra (Bhagn Devra)* Temple is no ordinary tantric temple, but is a *yogini* temple. There used to be sculptures of the 64 *yoginis* at the temple. All these sculptures have been taken away, however remains of one such sculpture in its majesty can still be seen.



Map No 7 : Important Structure in Ramgarh Crater

Image No. 8 : The Bhand-Devra Shiva Temple भण्डदेवरा of Ramgadh.

Image No. 9 : Fallen Carved Stones of Temple are Strewn Around

Image No. 10 : Carving on Pillars if the Temple

Image No. 11 : Carving on the Roof of the Temple

An annual fair is also organised during *Kartik Poornima* at the ***Kisnai*** and ***Annapurna Devi*** temples situated in natural cave atop the Ramgarh hill, about 750 stairs were constructed in 1791 CE by Jhala Zalim Singh (1730-1823, the Dewaan of Kota kingdom) for reaching the temple on the hill top. The interesting aspect of this temple is that the Devi is offered of *Meva* (dry fruits), vegetarian *prashaad* the food offering in the temple –"this is not just a food to eat but the physical presence of God's blessing to you", while the other is offered *Maas-Madira* (mutton-alcohol); at the time of *Prashaadi* (food offerings) a curtain is drawn between the two deities.

Image No. 12 : Stepped Route to Annapurna Cave Temple located on the rim of the collapsed Central Uplift ring of hills

(Credits : J. K. Sharma, Convenor, Baran Chapter, INTACH)

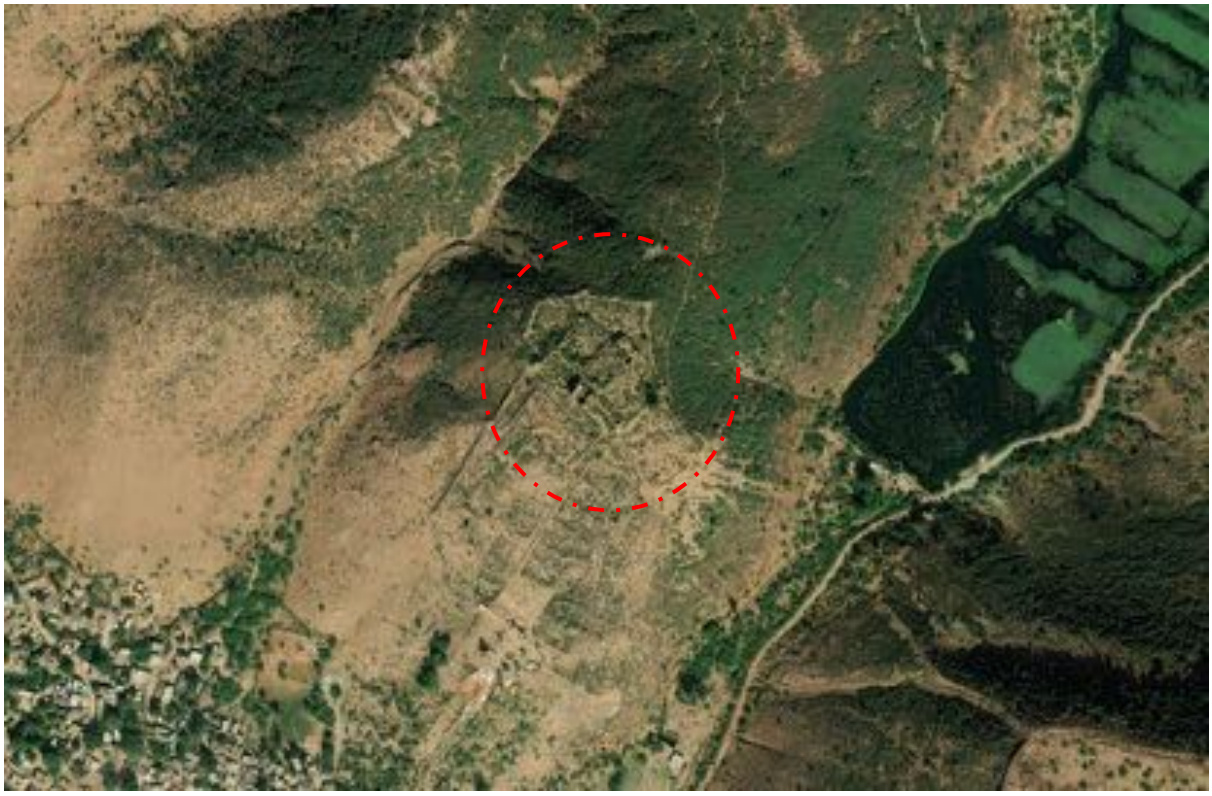


Image No. 13 : Google Satellite View of Fort Ruins (Ramgadh Kila) on South Rim

Image No. 14 : Ruins of the Fort that once stood magnificently on the Rim

Image No. 15 : The ruins of the Ramgadh Kila on the rim of the collapsed central uplift of the Ramgarh Crater. Note the heavily built entry gate, watchtower and the palace

Image No. 16 : View of the Ruined Fort

Image No. 17 : Google Satellite View of linear lake (Pushkar Jheel) in the Central Depression

Image No. 18 : Aquatic Birds in Lake [January, 2020]

Image No. 19 : Red-Crested Pochard swimming and feeding in the lake-Pushkar Jheel

Image No. 20 : Wave Pattern Created by Ducks on the Lake Surface

Image No. 21 : Dense Vegetation on the Inner Slope of the Central Depression (The Region is Marked as Protected Forest)

3.5 Protection Recommendations as well as Notifications Required

The area is under the State Forest Department; hence it is well protected by the law of Department of Forest and Environment, especially the Rajasthan Forest Act 1953. Additionally, the State Department of Archaeology and Museums controls the built heritage of the area and is protected by its regulations. It is to be ensured that these regulations are strictly applied to protect the natural as well as the human made heritages. This area needs to be developed as per the norms of "Criteria of selection of a site to be included on the World Heritage List" of UNESCO[4] as it does fulfil two of the ten criteria given in the list, namely (vii) "To contain superlative natural phenomena or area of exceptional natural beauty and aesthetic importance"; and also under the criterion (iii) "To bear a unique or at least exceptional testimony to a cultural tradition or to a civilization which is living or has disappeared". Thus, Ramgarh is a Natural cum Cultural Heritage Site. There are well-established elements explained in the UNSECO Web Page, which could be adopted for this site to develop it as per international parameters[5].

A bill was introduced in Rajya Sabha by the name of "THE NATIONAL COMMISSION FOR HERITAGE SITES BILL, 2009" but it was withdrawn subsequently. Its following components need to established by the law so that UNESCO could favourably consider a site that fulfils these parameters (these are similar or based on the UNESCO components). As per the Bill :

- **"Natural heritage site" shall include**
    a) **Natural sites** or precisely delineated natural areas which are of outstanding value from the point of view of science, conservation or natural beauty;
    b) **Geological and Physiographical formations** and precisely delineated areas which constitute the habitat of threatened species of animals and plants and are of outstanding value from the point of view of science or conservation;
    c) **Natural features consisting of physical and biological formations** or groups of such formations, which are of outstanding value from the aesthetic or scientific point of view;
- **"Mixed cultural and natural heritage site"** shall include properties which satisfy a part of the attributes of both cultural heritage site and natural heritage site;

- **"Cultural landscape"** includes cultural properties representing the combined works of man and the nature and illustrative of the evolution of human society and settlement over a time, under the influence of the physical constraints and opportunities presented by their natural environment and of successive social, economic and cultural forces, both external and internal;

[4](*cf.* https://whc.unesco.org/en/criteria/)
[5]Cf. http://whc.unesco.org/en/list/1513,http://whc.unesco.org/en/list/?type=mixed

3 PROMOTION OF TOURISM AT THE SITE

The site has great potential to become a popular destination for tourists in this upcoming "Hadoti Circuit", if it is suitably promoted by the State and Union Ministries of Tourism. However, the absence of tourism infrastructure and its mention on the Tourism Department website at present dissuades travel to the crater. While an appropriate promotion strategy is essential to launch the site on tourism circuits [perhaps in combination with other geoheritage sites in Rajasthan].

The site is under the jurisdiction of State Forest Department and the region has been notified as “Protected Forest”. Ramgarh Crater has earned global recognition by **Meteoritical Society**, the US based world body for meteorites (2020). This recognition is expected to give a major boost to this geoheritage site, as it has been lying neglected for decades. A geoconservation plan should be prepared to safeguard it and to promote it as green tourism site. By providing basic tourism facilities, site can be promoted as a geotourism site, which could help in spreading awareness among people regarding the importance of Ramgarh Crater. **All plans and projects need to achieve global standards to achieve parity with recognized tourism sites abroad.** Geotourism would also establish a fresh revenue stream and generate livelihood opportunities for local people. The following measures are recommended to make the site welcoming to tourists and travelers:

3.1 Recommendations

- **Biodiversity Survey:** Forest department should conduct a biodiversity survey within and without the crater region so as to establish baseline data and identify the local flora and fauna and ecological processes. Native vegetation should be promoted on the external slopes to prevent soil erosion.

- **Buffer Zone:** A Buffer Zone is proposed around the Ramgarh Crater to prevent defacing of possible destruction of the geological features. It is proposed that the 500 m buffer line is to be notified from the edge of the Protected Forest. This Buffer Zone shall be a no intervention zone with the intent of keeping the entire precinct pristine and unsullied. The existing Settlements falling inside the proposed Buffer Zone would have building height restrictions of 8m. Chimneys and mining activity are to be avoided in this zone.

- **Interpretation Complex:** An interpretation complex is proposed at old parking area, which would include Museum, Restaurant, Souvenir shop, Public conveniences, Cycle Stand, E-rickshaw Parking and Hot air balloon.
    - A modern Interpretation Centre should be built at marked location on the proposals map, with appropriate display system of the various aspects of

meteorites and impact craters. The scattered architectural elements lying scattered in the area should be displayed with description.

- **Hot Air Balloon:** Two hot air balloons would be operated from a 1 acre site near the interpretation centre. The balloons would be cable guided for vertical movement only, rising to a height of 1800 m to appreciate the circularity of the crater.

- **Gateway:** An Arch structure gateway would be proposed at the entrance of the crater (marked on the proposal map). Gateway structure would provide a sense of entry into the crater boundary. Gateway would also e a point of regulating and monitoring visitors. Gateway area would be equipped with a site map, description folder, Do & Don't instructions, accessible and prohibited zones and major tourist infrastructure locations.

- **Parking Area:** An area of about 2500 sqm will have to be allocated for the parking facilities. A parking lot has been proposed for 20 Buses and 30 Cars. The parking lot is located outside the crater, near the gateway. No private vehicles would be allowed inside the gateway. The Parking lot would be equipped with public convenience facilities. E-vehicles would be available at the parking lot to take tourists inside the crater.

- **Bycycle Pickup Point & Bycycle Stand** - A bycycle pick up point with cycle stand for 50 bikes have been proposed within interpretation complex. As the region is noise free zone, bycycle would provide free and ease movement in the region. Bycycle stand for about 25 bikes would be also proposed near important Tourist spots.

- **No-Noise Zone:** Area bounded by the crater structure would be no-noise zone. The movement inside the crater will be on e-rickshaw or by-cycle. This would provide livelihood opportunities for local people. No loudspeaker or any electronic sound equipment should be allowed in the crater region.

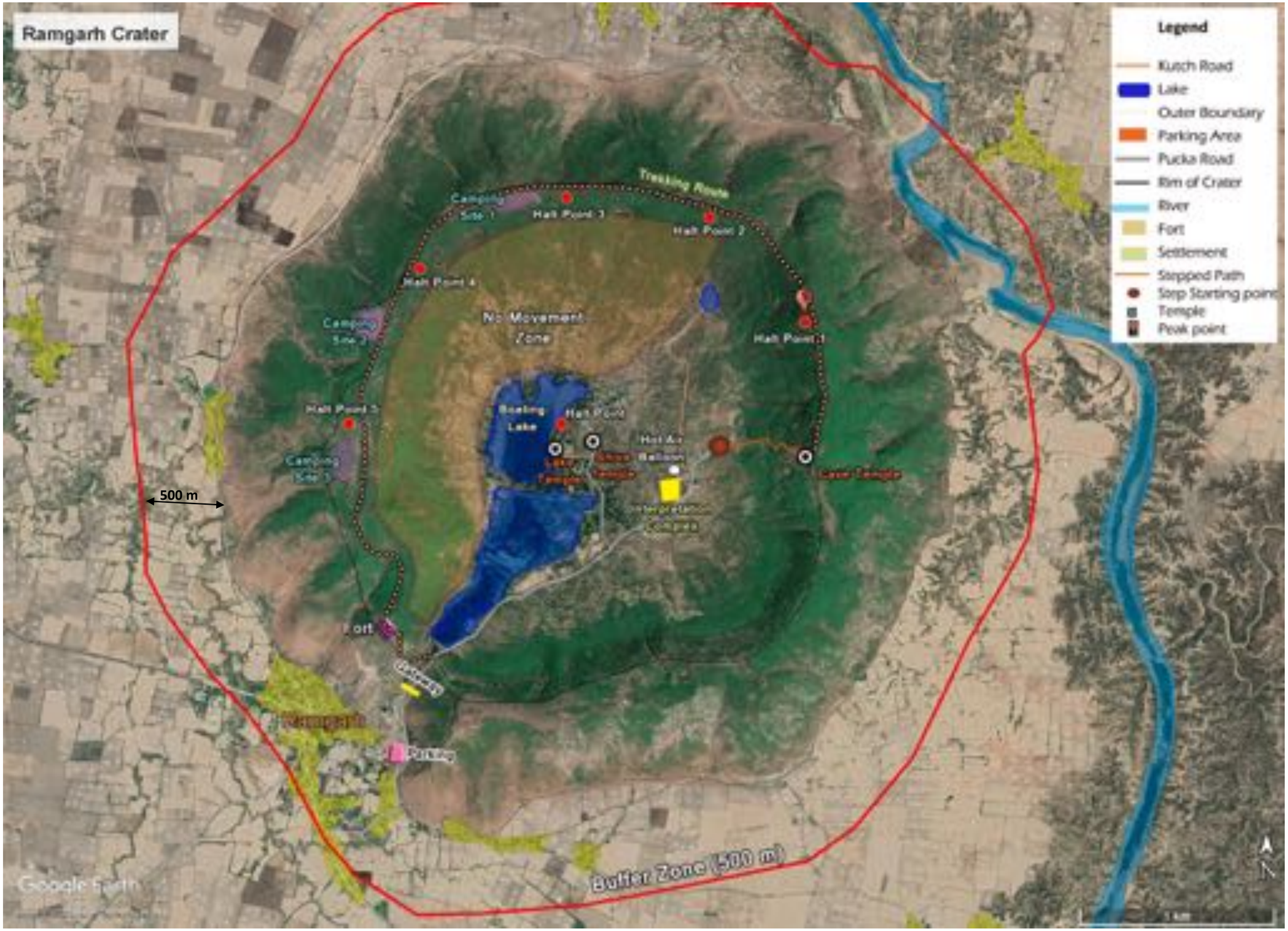
- **Lake Improvement:** Both lakes would be interconnected to maintain the water level.
  - Lake on the south side would be developed naturally. No activities should be allowed inside this lake.
  - East edge of the northern lake would be developed. A walking pathway would be proposed along the eastern edge of the lake with few halt points. Paddle boating facilities would be introduced. No boating would be permitted during winters [15 November to 1 March] to host migratory birds.
  - Indian carps would be introduced in the lakes to attract birds

- **Restoration of Temples & Fort:** The Bhand Devra temple must be restored in authentic fashion. The Fort, too, would need to be similarly restored to host visitors [accommodation and cafe could be considered here]**.** Instead of Bhand-Devra, which is a later name for a vandalized structure, the temple should be named ***Ulkapindeshwar*** (उल्कापिंडेश्वर, *Ulkapind* उल्कापिंड is a meteorite in Hindi) so that the public can correlate with the origin of this nature's wonder.

- **Stepped Route Facilities:** Existing stepped route to Annapurna Devi Cave Temple on the top of the rim would be repaired as per requirement. Halt points, drinking water and toilet facilities would be provided in the middle of the route.

- **Trekking Route:** A trekking route of 2M wide would be developed along the rim of the crater starting from the Annapurna Devi Cave Temple to ruined fort in the south of the crater. The length of the track would be 6km approx. Some viewpoints/pause points would be marked along the route and 3 camping sites would be developed at appropriate locations (as marked in the proposal map). Trekking route would end at the ruined fort and a stepped route would be developed from the fort to the main road below.

- **Signage:** Signage boards would be put up at designated locations. Signages will display the site map, information about the particular structure and Do & Don't instructions.



Map No 8 : Proposed Development Plan of Ramgarh MIC

Image No. 22 : INTACH Team at Ramgarh Crater Site

Image No. 23 : Central Uplift-Rebound Mound-the Natural Shivling

4 GLOSSARY OF KEY TERMS OF METEORITES

4.1 Meteor

"Meteor, known colloquially as a *shooting star* or *falling star*, is the visible passage of a glowing meteoroid, micrometeoroid, comet or asteroid through Earth's atmosphere, after being heated to incandescence by collisions with air molecules in the upper atmosphere, creating a streak of light via its rapid motion and sometimes also by shedding glowing material in its wake. Although a meteor may seem to be a few thousand meters from the Earth, meteors typically occur in the mesosphere at altitudes from 76 to 100 km. The root word meteor comes from the Greek meteōros, meaning "high in the air". Millions of meteors occur in Earth's atmosphere daily. Most meteoroids that cause meteors are about the size of a grain of sand, i.e. they are usually millimetre-sized or smaller. Meteoroid sizes can be calculated from their mass and density which, in turn, can be estimated from the observed meteor trajectory in the upper atmosphere. Meteors may occur in showers, which arise when Earth passes through a stream of debris left by a comet, or as "random" or "sporadic" meteors, not associated with a specific stream of space debris. A number of specific meteors have been observed, largely by members of the public and largely by accident, but with enough detail that orbits of the meteoroids producing the meteors have been calculated. The atmospheric velocities of meteors result from the movement of Earth around the Sun at about 30 km/s, the orbital speeds of meteoroids, and the gravity well of Earth.

Meteors become visible about 75 to 120 km above Earth. They usually disintegrate at altitudes of 50 to 95 km. Meteors have roughly a fifty percent chance of a daylight (or near daylight) collision with Earth, then it is called a **Meteorite**. Most meteors are, however, observed at night, when darkness allows fainter objects to be recognized. For bodies with a size scale larger than 10 cm to several meters meteor visibility is due to the atmospheric ram pressure (not friction) that heats the meteoroid so that it glows and creates a shining trail of gases and melted meteoroid particles. The gases include vaporized meteoroid material and atmospheric[6]

4.2 Meteoroid

Meteoroid is a small rocky or metallic body in outer space. Meteoroids are significantly smaller than asteroids, and range in size from small grains to one meter wide objects. Objects which are smaller than this is classified as micrometeoroids or space dust. Most are fragments from comets or asteroids, whereas others are collision impact debris ejected from bodies such as the Moon or Mars. When a meteoroid, comet, or asteroid enters Earth's atmosphere at a speed typically in excess of 20 km/s (72,000 km/h), aerodynamic heating of that object produces a streak of light, both from the

[6] - https://en.wikipedia.org/wiki/Meteoroid

glowing object and the trail of glowing particles that it leaves in its wake. This phenomenon is called a meteor or "shooting star". A series of many meteors appearing seconds or minutes apart and appearing to originate from the same fixed point in the sky is called a meteor shower. If that object withstands ablation from its passage through the atmosphere as a meteor and impacts with the ground, it is then called a meteorite.
An estimated 15,000 tonnes of meteoroids, micrometeoroids and different forms of space dust enter Earth's atmosphere each year[7].

4.3 Meteorite Impact Crater

"Impact Crater is an approximately circular depression in the surface of a planet, moon, or other solid body in the Solar System or elsewhere, formed by the hypervelocity impact of a smaller body. In contrast to volcanic craters, which result from explosion or internal collapse. Impact craters typically have raised rims and floors that are lower in elevation than the surrounding terrain. Although Meteorite Crater is perhaps the best known example of a small impact crater on Earth, impact craters range from small, simple, bowl-shaped depressions to large, complex, multi-ringed impact basins[8]."

4.4 Crater Diameter/Depth Ratio

Impact craters of the Earth are subdivided into three distinctive groups based upon their shape, which are, in turn, related to crater size. The simple impact crater is a bowl-shaped feature (usually less than 2 km in diameter) with relatively high depth to diameter ratio. The complex impact crater has a low depth to diameter ratio and possesses a central uplift and a down-faulted and terraced rim structure. Complex impact craters on the Earth range from the upper limit of simple impact craters to approximately 100 km in diameter. Multi-ring craters (also called multi-ring basins) are impact craters with depth to diameter ratios like complex impact craters, but they possess at least two outer, concentric rings (marked by normal faults with downward motion toward crater centre). Earth has five known multi-ring impact basins, but many more are known on the moon and other planets and satellites in the solar system, where they range from several hundred kilometres up to 4,000 km in diameter. The gravity of a planet or satellite and the strength of the surface material determine the transition diameter from simple to complex and complex to multi-ring impact crater morphology[9].

4.5 Central Peak Uplift

Complex craters are a type of large impact crater morphology. Above a certain threshold size, which varies with planetary gravity, the collapse and modification of the transient

[7] https://en.wikipedia.org/wiki/Meteoroid
[8] https://en.wikipedia.org/wiki/Impact_crater

[9] -https://www.encyclopedia.com/science/encyclopedias-almanacs-transcripts-and-maps/impact-crater

cavity is much more extensive, and the resulting structure is called a *complex crater*. The collapse of the transient cavity is driven by gravity, and involves both the uplift of the central region and the inward collapse of the rim. The central uplift is not the result of *elastic rebound* which is a process in which a material with elastic strength attempts to return to its original geometry; rather the uplift is a process in which a material with little or no strength attempts to return to a state of gravitational equilibrium.

Complex craters have uplifted centres, and they have typically broad flat shallow crater floors, and terraced walls. At the largest sizes, one or more exterior or interior rings may appear, and the structure may be labelled an *impact basin* rather than an impact crater. Complex-crater morphology on rocky planets appears to follow a regular sequence with increasing size: small complex craters with a central topographic peak are called *central peak craters*, for example Tycho; intermediate-sized craters, in which the central peak is replaced by a ring of peaks, are called *peak ring craters*, for example Schrödinger; and the largest craters contain multiple concentric topographic rings, and are called *multi-ringed basins*, for example Orientale. On icy as opposed to rocky bodies, other morphological forms appear which may have central pits rather than central peaks and at the largest sizes may contain very many concentric rings – Valhalla on Callisto is the type example of the latter[10].

4.6 Impact Melt

When a meteor strikes a planet's surface, the energy release from the impact can melt rock and soil into a liquid. If the liquid cools and hardens quickly into a solid, impact glass forms before the atoms have time to arrange into a crystal lattice. Impact glass is dark brown, almost black, and partly transparent. Impactite includes shock-metamorphosed target rocks, melts (suevites) and mixtures of the two, as well as sedimentary rocks with significant impact-derived components (shocked mineral grains, tektites, anomalous geochemical signatures, *etc.).* In June 2015, NASA reported that impact glass has been detected on the planet Mars. Such material may contain preserved signs of ancient life—if life existed[11].

[10] https://en.wikipedia.org/wiki/Complex_crater See also https://www.youtube.com/watch?v=6swY05e2iT4

[11] https://en.wikipedia.org/wiki/Impactite

5 BIBLIOGRAPHY

GSI Web portal, Geotourism, 2020:
https://www.gsi.gov.in/webcenter/portal/OCBIS/page17/pageGEOTOURISM?_adf.ctrl-state=xupfomnjq_5&_afrLoop=12981221348219922#!

Iyengar, R.N., 2010. Comet and Meteoritic Showers in the R.GVEDA and their Significance. Indian Journal of History of Science, 45.p. 1-32 (and his WebPages through Google Search)

Kenkmann T., Wulf G. and Agarwal A., 2020, Ramgarh, Rajasthan, India. A 10 km diameter complex impact structure. Meteoritics and Planetary Science, v. 55 (4) pp. 936-961

Mishra, S., Srivastava, P.K. and Arif Md., 2018. Remote sensing, Structural and Rock Magnetic Analysis of the Ramgarh Structure of SE Rajasthan, Central India, Further clues to its Impact Origin and Time of Genesis. In: Structural Geology and Tectonics: Indian Context. Editor S. Mukherjee. Springer, p. 327-352. (*cf*. references contained in it)

Pati, J. K., Reimold, W. U., Koeberl, C. and Pati, P., 2008. The Dhala Structure, Bundelkhand Craton, Central India – Eroded remnant of a large Palaeo-Proterozoic impact structure. Meteorit. Planet. Sci., 43, p. 1383–1398.

Ranawat, P. S. 2016: Monograph on National Geological Monuments and Potential Geoheritage Sites of Rajasthan, INTACH Publication, Udaipur. p. 82-85.

Schmeider, M and Kring, D. A., 2020, Earth's Impact Events Through Geologic Time: A List of Recommended Ages for Terrestrial Impact Structures and Deposits. Astrobiology, v. 20 (1).pp. 91-140.

Sisodia, M. S., Lashkari, G., and Bhandari, N., 2006. Impact origin of the Ramgarh Structure, Rajasthan: some new evidences: Journal of Geological Society of India, v. 67, p. 423-431.

WebPages on "meteorite" through Google search.

6 ANNEXURE

Signage Details:

1. A large board at the SSW entrance (suggested text as given below)

WELCOME TO RAMGARH GEOHERITAGE, ARCHAEOLOGICAL, SPIRITUAL, CULTURAL SITE (DEV-VANEE)

Image No. 24 : Welcome Gate in Kota Sandstone or Limestone Facing

2. Central Uplift Mound and geomorphology of rim, base, outside elevation &inside elevation(suggested text as given below)

RAMGADH METEORITE CRATER

The Ramgadh Meteorite Impact Crater (MIC) displays a circular bowl-like geomorphologic depression of about 4 km diameter that is surrounded by a chain of hills conspicuously rising above nearly plain area of Vindhyan sedimentary rocks (240 m MSL). The central area of the crater has a small “Central Uplift Mound”, considered a "Natural Shivling" hence a few Shiv Temples were built near it in the tenth century CE. including the popular Shiv Temple (Ulkapindeshwar).

The exotic Ramgarh structure remained an enigmatic landform for long, it was studied by different workers from Geological Survey of India and different Universities, it has now been concluded that:

1. The 200 m high, ~4-km diameter ring structure of hills is result of a collapse of the dome that had formed as a central uplift due to the impact of an estimated 1.0 km diameter meteorite.
2. The complex meteorite impact crater is of 10-km diameter, making it slightly smaller than the 11-km Dhala (MP) MIC, but larger than the 1.8-km Lonar MIC (Maharashtra).
3. The moderately oblique (45°–30°,*cf. Dr. Hiroshi* watercolour painting) impact occurred into a shallow water regime on the horizontally lying upper Vindhyan sedimentary rocks,1000–1070 million years ago (mya).
4. The impact possibly occurred during middle-upper Jurassic Period, some 165 (mya).

3. The Central Uplift Mound(suggested text as given below)

THE CENTRAL UPLIFT MOUND & SHIV TEMPLE

When a large meteorite, in this case having an estimated diameter of 1.0 km, strikes the earth it has a tremendous momentum (mass x velocity), because of which the entire material of the meteorite is fragmented and ionized when it hits the surface of the earth. But the central part of the crater floor/ground, forms a small mound – very similar to a Shivling. It is quite likely that because of this resemblance, the ancient people built a Shiva Temples that were vandalized during the medieval period and one was given a name of Bhand-Devra,(भण्डदेवरा), this name is derived from the terms भग्नदेवग्रह destroyed/wrecked/vandalized temple. But as mentioned on the stone inscriptions, the original temple was built in the 10th century by Raja Malaya Verma of Nag dynasty of Malwa as a memorial of his victory over his enemies and as a tribute showing his gratitude to Lord Shiva whom he held in esteem. With the passage of time in 1162 CE, the edifice was renovated by Raja Trisna Verma of Med Dynasty. Since it occurs within a meteorite crater, the temple should be given a more respectable name, say "ULKAPINDESHWAR" from *Ulkapind*-meteorite; the temple too should be restored as per the original layout & pattern.

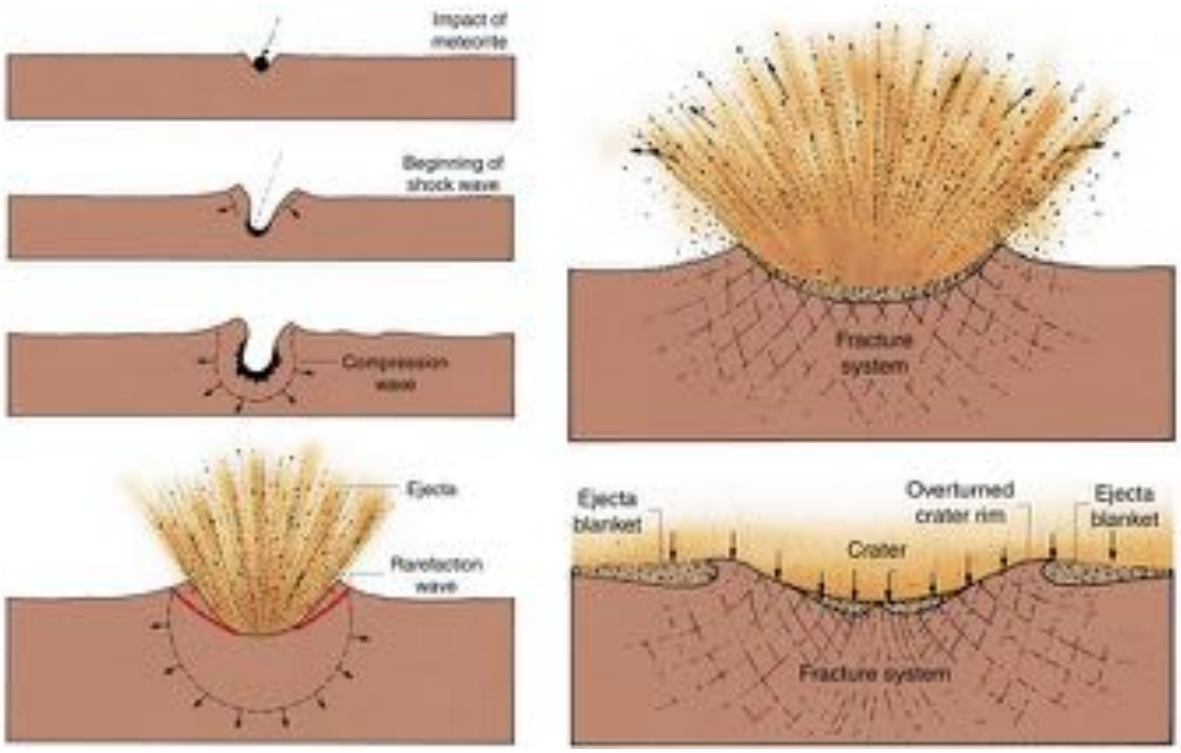


Figure No. 9 : A Visualized 'Serial Diagram' Depicting Meteorite Impact Crater Formation

Image No. 25 : Yet Another Collage of Multi-Heritage Attributes of Ramgarh GHS

Image No. 26 : View of Fort Structure from Southern Lake

(Credits : J. K. Sharma, Convenor, Baran Chapter, INTACH)

Image No. 27 : Bird Eye View of Shiv Temple at Ramgarh MIC
(Credits : J. K. Sharma, Convenor, Baran Chapter, INTACH)

Image No. 28 : Bird Eye View of Both Lake at Ramgarh MIC
(Credits : J. K. Sharma, Convenor, Baran Chapter, INTACH)

SKYFALL, Birth of a Meteorite Impact Crater, Ramgadh, Rajasthan, India

I am a geographer and a landscape painter. I rarely paint from a photograph but painting scenes that are beyond planet earth is another matter. I once enjoyed rendering a volcanic eruption on Jupiter's moon, Io, from images taken by the camera on NASA's Galileo Orbiter spacecraft. A request from my geologist friend Professor Pushpendra Ranawat to paint the moment of impact of a meteorite on the Kota Plateau offered a different kind of challenge. It happened eons before man walked the earth. The only record of this natural drama is the Ramgadh Crater, not yet fully explored and documented as a meteorite impact crater. After garnering information on the estimated size of the meteorite, angle and direction of impact, and location of the Indian Plate with surface topography and appearance, I claimed artistic license and went to work. Of necessity, this painting of the birth of a potential geoheritage site is essentially the outcome of my imagination. I painted it on a rare 'cratered' Dutch paper for the 150th ANNIVERSARY OF THE DISCOVERY OF Ramgadh structure in 1869 by F.R. Mallet of GSI.

Hiroshi Shimazaki, https://www.hiroshishimazaki.com/

Thanks Prof. Dr. Hiroshi Shimazaki for the painting and the 'Artist's Note'. The following is our Note for this 'Nature's Wonder'-the ONLY one in Rajasthan and a third on India :

The Ramgadh Meteorite Impact Crater (रामगढ़ MIC) displays a circular bowl-like geomorphologic depression of about 4 km diameter that is surrounded by a chain of hills conspicuously rising above nearly plain area of Vindhyan sedimentary rocks (240 m MSL). The central area of the crater has a small "Central Uplift Mound", considered a "Natural Shivling" hence a few Shiv Temples were built near it in the tenth century CE including the popular Shiv Temple (Ulkapindeshwar). The exotic Ramgarh structure remained an enigmatic landform for long, it was studied by different workers from Geological Survey of India and different Universities, Indian as well as foreign. It is now concluded that:

1. The 200 m high, ~4-km diameter ring structure of hills is result of a collapse of the dome that had formed as a central uplift due to the impact of an estimated 1.0 km diameter meteorite. 2. The complex meteorite impact crater is of 10-km diameter, making it slightly smaller than the 11-km Dhala (MP) MIC, but larger than the 1.8-km Lonar MIC (Maharashtra). 3. The moderately oblique (45°–30°,cf. painting above) impact occurred into a shallow water regime on the horizontally lying upper Vindhyan sedimentary rocks of 1000–1070 million year age (mya). 4. The impact possibly occurred during middle-upper Jurassic Period, some 165 mya. 5. A fertile valley surrounded by protective forested hills (a typical Gooha-Doorg terrain गुहा-दुर्ग क्षेत्र) with a fresh water body in it are the favourable attributes for human settlement in this nature's gift in the Hadoti area. This is evident from the human activity in it for thousands of years.

ABOUT INTACH

The Indian National Trust for Art and Cultural Heritage is a national NGO registered under the Societies Act in 1984. The organization is recognized as a Centre of Excellence by GoI and is mandated to preserve and conserve the heritage of insdia. Headquartered at Delhi, the organization has volunteer chapter in 180 districts of the country. INTACH is organized in Divisions looking after Architectural Heritage, Material Heritage, Natural Heritage, Intangible Cultural Heritage, INTACH Heritage Academy, and Heritage Education.

NATURAL HERITAGE DIVISION (NHD)

Nature is the wellspring of culture and if nature thrives so will culture. Several organization work separately in the field of environment or of culture. Promotion of the Natural Heritage includes both the biotic as well as abiotic (geodiversity) aspects. The Natural Heritage Division's unique niche is hard core environmental issues and projects. Over the years the diverse project of the Division have generated substantial in-house experience and capacities but also coalesced into thematic programs.

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