Terrestrial Impact Structures—A Bibliography

By Jacquelyn H. Freeberg

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ILLUSTRATION

PLATE 1. Sketch map showing locations of terrestrial impact structures In pocket
ABSTRACT

This bibliography lists 110 features for which origin by meteoritic impact has been suggested and gives a comprehensive group of references for each feature. Annotations for the more significant contributions to the literature are included. The structures are divided into six categories, and their geographic locations are indicated on a sketch map.

INTRODUCTION

The compilation of a bibliography on terrestrial impact structures was prompted by an increasing interest in meteoritic impact as a factor in the geologic process and by the analogy of these structures to similar features on the moon. The bibliography is comprehensive in order to serve as wide a range of public interest as possible. Something of an attempt to evaluate the entries has been made by reviewing as many of the articles as possible and by including in the bibliography annotations for some of the more significant contributions to the literature of each structure.

The first section of the bibliography lists the references on distribution and general characteristics of impact structures in order to provide information on a large number of structures; these papers are noted in the lists for specific structures by a “see also” reference. Otherwise, any set of citations for a particular structure is intended to constitute a complete bibliography of that structure. Cutoff date on entries included is December 1964.

Most structures for which an impact origin has been suggested in the literature are included and are alphabetically listed in the contents. Names by which features are known naturally vary; alternate names appear in the text and also in an index. Locations of the structures are shown on the accompanying sketch map (pl. 1). The geographical coordinates for each structure are given under its listing in the bibliography.

As search for undiscovered craters and research on the geology of those presently known continues, the list can be expected to change, perhaps rapidly.
Currently, only 11 of the 110 features listed here are universally accepted as meteorite craters. Some indication of the nature of, and reason for including, the others seems useful. A classification using six categories adapted from Shoemaker and Eggleton,\(^1\) with a list of structures belonging to each group, follows. The category to which each structure is assigned is also noted in the bibliography.

**Category 1:** Craters, or clusters of craters, with associated meteorites.
- Barringer Crater, Ariz.
- Boxhole Crater, Australia
- Campo del Cielo Craters, Argentina
- Dalgaranga Crater, Australia
- Haviland Crater, Kans.
- Henbury Craters, Australia
- Kaalijärvi Craters, Estonia
- Odessa Craters, Tex.
- Sikhote-Alin Craters, U.S.S.R.
- Wabar Craters, Saudi Arabia
- Wolf Creek Crater, Australia

**Category 2:** Craters with form and structure of meteorite craters and associated phases probably of shock origin.
- Aouelloul Crater, Mauritania
- Clearwater Lakes, Canada
- Holleford Crater, Canada
- Lake Bosumtwi, Ghana
- Richât Crater, Mauritania
- Rieskessel, Germany

**Category 3:** Craters with the form and structure of meteorite craters.
- Lonar Lake, India
- New Quebec Crater, Canada
- Pretoria Salt Pan, South Africa
- Steinheim Basin, Germany
- Talemzane Crater, Algeria

**Category 4:** Deeply eroded or buried structures possibly of impact origin.
- Brent Crater, Canada
- Crooked Creek structure, Mo.
- Decaturville disturbance, Mo.
- Flynn Creek structure, Tenn.
- Glasford structure, Ill.
- Howell structure, Tenn.
- Jeptha Knob structure, Ky.
- Kentland structure, Ind.
- Kilmichael structure, Miss.
- Manicouagan-Mushalagan Lakes area, Canada
- Manson structure, Iowa
- Middlesboro Basin, Ky.

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CLASSIFICATION OF STRUCTURES

Serpent Mound structure, Ohio
Sierra Madera structure, Tex.
Versailles structure, Ky.
Vredefort structure, South Africa
Wells Creek area (main structure), Tenn.

Category 5: Features probably of nonimpact origin.
Al Umchaimin Crater, Iraq
Arnhem Land Crater, Australia
Carolina Bays, U.S.
Crater Elegante, Mexico
Crestone Crater, Colo.
Duckwater Crater, Nev.
Eyless Peninsula Craters, Australia
Franktown Crater, Canada
Gwarkuh Crater, Iran
Hungarian Plain, Hungary-Romania
Malha Crater, Sudan
Mount Doreen Crater field, Australia
Panamint Crater, Calif.
Semsiyat dome, Mauritania
Socotra Crater, Socotra
Tiffin Crater, Iowa
Tunguska event, U.S.S.R.
Upheaval Dome, Utah

Category 6: Structures for which more data are required for classification.
Amak Island Crater, Alaska
Amguid Crater, Algeria
Baghdad Craters, Iraq
Basra Crater, Iraq
Carswell Lake structure, Canada
Chinge site, U.S.S.R.
Deep Bay, Canada
Des Plaines disturbance, Ill.
Dycus disturbance, Tenn.
Dzioua Craters, Algeria
Ellef Ringnes Island Craters, Canada
Glover Bluff structure, Wis.
Gulf of St. Lawrence arc, Canada
Hagens Fjord Craters, Greenland
Hérald Craters, France
Ilumetsa Craters, Estonia
Ka-imu-hoku, Hawaii
Kalkkop structure, South Africa
Keeley Lake, Canada
Köfels site, Austria
Lac Couture, Canada
Lake Dellen, Sweden
Lake El'gytkhyn, U.S.S.R.
Lake Humeln, Sweden
Lake Michikamau, Canada
Lake Mien, Sweden
Lake Siljan, Sweden
Macamic Lake, Canada
Mecatina Crater, Canada
Melville Island Craters, Canada
Menihek Lake area, Canada
Merewether Crater, Canada
Merriwell Lake, Canada
Morasko Craters, Poland
Murgab Craters, U.S.S.R.
Nastapoka Islands arc, Canada
Nebiewale Crater, Ghana
New Mexico Crater, N. Mex.
Paris (Sucy-en-Brie and Alentours) lakes, France
Parry Sound Crater, Canada
Patomskii Crater, U.S.S.R.
Pilot Lake, Canada
Sault au Cochons structure, Canada
Sayan Crater, U.S.S.R.
Sudbury Basin, Canada
Temimichât-Ghallaman Crater, Mauritania
Tenoumer Crater, Mauritania
Tvären Bay, Sweden
Ungava Bay, Canada
Wells Creek area (three craters), Tenn.
West Hawk Lake, Canada
Wilbarger dome, Tex.
Wilkes Land structure, Antarctica
Winkler Crater, Kans.

SERIALS

The following list gives abbreviated titles of serials cited in this bibliography, with complete titles as used in library catalogs and union lists of serials and place of publication. The issuing agency, if not a commercial publisher, is included.

Akad. Nauk SSSR Comptes Rendus, Doklady—
Akad. Nauk SSSR Doklady—
Akad. Nauk SSSR Izv. ser. geog. i geofiz.——
Akad. Nauk SSSR Vestnik—


Am. Geologist—American Geologist. Minneapolis, Minn.


Am. Philos. Soc. Proc.—


Am. Scientist—American Scientist. Society of the Sigma Xi. New Haven, Conn.


Arctic—Arctic. Arctic Institute of North America. Ottawa, Canada.


TERRESTRIAL IMPACT STRUCTURES—A BIBLIOGRAPHY

Austria Geol. Bund. Verh.—Austria, Geologische Bundesanstalt, Verhandlungen. Vienna, Austria.
Bayerische Akad. Wiss. Sitzungsber.—Bayerische Akademie der Wissenschaften, Sitzungsberichte. Munich, Germany.
Beitr. Geophysik—Beiträge zur Geophysik (also Gerlands Beiträge zur Geophysik). Leipzig, Germany.
Canada Geol. Survey Bull.—Canada Geol. Survey Map—Canada Geol. Survey Paper—
Časopis—Časopis Československých ústavů astronomických. Prague, Czechoslovakia.
Chemie der Erde—Chemie der Erde. Jena, Germany.
Compressed Air Mag.—Compressed Air Magazine. Easton, Pa.
Copenhagen Univ. Mus. Mineralogie et Geologie Commun. Geol.—Copenhagen University, Muséum de Minéralogie et de Géologie, Communications Géologiques. Copenhagen, Denmark.
Desert Mag.—Desert Magazine. Palm Desert, Calif.
Field and Laboratory—Field and Laboratory. Dallas, Tex.
Forschung. und Fortschr.—Forschungen und Fortschritte. Berlin, Germany.
Geochemistry [English translation]—Geochemistry [English translation]. Geochemical Society, Washington, D.C.
Geog. Wochenschr.—Geographische Wochenschrift. Frankfurt, Germany.
Geokhimiya—Geokhimiya. Akademiya Nauk, Moscow, U.S.S.R.
Geol. Jahrb.—Geologisches Jahrbuch. Geologischen Landesanstalten der Bundesrepublik Deutschland. Hannover, Germany.
Geol. Rundschau—Geologische Rundschau. Stuttgart, Germany.
Geol. Soc. America Bull.—
Geol. Soc. America Guidebook for field trips—
Geol. Soc. America Proc.—
Geol. Soc. America Spec. Paper—

Geol. Soc. South Africa Proc.—

Geol. Soc. South Africa Trans.—

Geol. Soc. South Africa Trans. and Proc.—


Geologie und Bauwesen—Geologie und Bauwesen. Vienna, Austria.


Gold Coast Geol. Survey Bull.—

Gold Coast Geol. Survey Rept.—


Griffith Observer—Griffith Observer. Griffith Observatory. Los Angeles, Calif.


Ingenieur—De Ingenieur. Paris, France.


Kansas Acad. Sci. Trans.—Kansas Academy of Science, Transactions. Lawrence, Kans.


Kommunist [Yerevan]—Kommunist. Yerevan, U.S.S.R.

Kosmos [Stuttgart]—Kosmos. Stuttgart, Germany.


Meteorbeobachter—Der Meteorbeobachter. Meteorbeobachtungsgruppe München. Munich, Germany.


Meteoritika—Meteoritika. Akademiya Nauk SSSR. Moscow, U.S.S.R.
Mineralogist—Mineralogist. Menstone, Calif.
Mining Eng.—Mining Engineering. American Institute of Mining, Metallur-
gical, and Petroleum Engineers. New York, N.Y.
Mining Rev.—Mining Review. Salt Lake City, Utah.
State College, Miss.
Mississippi Geol. Survey Bull.—Mississippi Geological Survey, Bulletin. Uni-
versity, Miss.
Missouri Geol. Survey and Water Resources [Rept.]—Missouri Geological Sur-
vey and Water Resources, [Report]. Rolla, Mo.
Notes. Flagstaff, Ariz.
Natl. Acad. Sci. Proc.—National Academy of Sciences, Proceedings. Washing-
ton, D.C.
Academy of Sciences-National Research Council, Publication, Nuclear Science
Natl. Geog. Mag.—National Geographic Magazine. National Geographic So-
ciety. Washington, D.C.
Nat. History—Natural History. American Museum of Natural History. New
York, N.Y.
Natur und Volk—Natur und Volk. Senckenbergische Naturforscdende Gesell-
schaft. Frankfurt, Germany.
Naturwiss. Ver. Schwaben und Neuberg (e.v.) Augsburg Abh.—Naturwissen-
schaftlicher Verein für Schwaben und Neuberg (e.v.), Augsburg, Abhand-
lungen. Augsburg, Germany.
Naturwiss. Wochenschr.—Naturwissenschaftliche Wochenschrift. Deutsches
Naturwissenschaften—Die Naturwissenschaften. Gesellschaft Deutsches Natur-
forscher und Arzte, und die Max-Planck-Gesellschaft zur Forderung der
Wissenschaften. Berlin, Germany.
Verhandelingen. Amsterdam, The Netherlands.
Neues Jahrb. Mineralogie Geognosie Geologie und Petrefaktenk.—Neues Jahrbuch
für Mineralogie, Geognosie, Geologie und Petrefaktenkunde. Stuttgart,
Germany.
Neues Jahrb. Mineralogie Geologie und Paläontologie, Beilage-Band—
Neues Jahrb. Mineralogie Geologie und Paläontologie, Monatsh.—
Neues Jahrbuch für Mineralogie, Geologie und Paläontologie, Beilage-Band
and Monatshefte. Stuttgart, Germany.
New Mexico Univ. Pub. Meteoritics—University of New Mexico Publications in

Nordisk Astron. Tidsskr.—Nordisk Astronomisk Tidsskrift. Copenhagen, Denmark.


Observatory—Observatory, Royal Greenwich Observatory. Hallsham, England.


Ottawa Dominion Observatory Contr.—

Ottawa Dominion Observatory Pub.—

Ottawa, Dominion Observatory, Contributions and Publications. Ottawa, Canada.


Petermanns Mitt.—Petermanns Mitteilungen (also Petermanns Geographische Mitteilungen). Gotha, Germany.


Pop. Astronomy—Popular Astronomy. Goodsell Observatory, Northfield, Minn.


Priroda—Priroda. Moscow, U.S.S.R.


Problems of the North—Problems of the North [translation of Problemy Severa].

National Research Council. Ottawa, Canada.

Problemy Severa—Problemy Severa. Akademiya Nauk SSSR. Moscow, U.S.S.R.

Quebec Dept. Nat. Resources Prelim. Rept.—Quebec, Department of Natural Resources, Preliminary Report. Quebec, Canada.


Royal Soc. Canada Minutes Proc.—

Royal Soc. Canada Trans.—

Royal Society of Canada, Minutes and Proceedings and Transactions. Ottawa, Canada.


Science—Science. American Association for the Advancement of Science. Washington, D.C.


Smithsonian Contr. Astrophysics—Smithsonian Contributions to Astrophysics. Smithsonian Institution. Washington, D.C.


Smithsonian Misc. Colln.—Smithsonian Miscellaneous Collections. Smithsonian Institution. Washington, D.C.


Space Sci.—Space Science. Silver Spring, Md.

Space Technology Labs., Inc., Research Bibliography—


Sterne—Die Sterne. Leipzig, Germany.

Sternenwelt—Sternenwelt. Munich, Germany.

Studia Geol. Polonica—Studia Geologica Polonica. Polska Akademia Nauk. Warsaw, Poland.

Sudan Notes and Records—Sudan Notes and Records. Khartoum, Sudan.


Terra—Terra. Helsinki, Finland.

Texas Univ. Bull.—University of Texas, Bulletin. Austin, Tex.


Umschau—Umschau. Frankfurt, Germany.
DISTRIBUTION AND GENERAL CHARACTERISTICS OF IMPACT STRUCTURES

Ref.
1 Albritton, C. C., Jr., and Boon, J. D., 1937, Meteoritic craters and structures; Pan-Am. Geologist, v. 68, p. 304-305.

   Almost half this book is given to a comprehensive survey of sites of known or suspected impact origin. Most structures treated in the present bibliography are mentioned.

   This list was prompted by discussion at the 1960 meeting of the Meteoritical Society of the advisability of maintaining an official list of meteorite craters. Barringer gives location, size, and evidence for 27 “meteorite craters,” 13 “suspected meteorite craters,” and 12 “large fall sites.”
Ref.
The authors point out that the existence of fossil craters was first suggested in connection with cryptovolcanic structures and review evidence for impact origin of eight structures in the Canadian Shield; they are particularly interested in the theory and mechanics of crater formation.
Ref.

In three papers cited here (refs. 17, 18, 19), Boon and Albritton point out that the type of structure expected beneath large meteorite craters is strikingly similar to certain "cryptovolcanic structures" and that certain explosion structures previously attributed to volcanism might, in fact, be of meteoritic origin. (See also ref. 105.)

18 —— 1937, Meteorite scars in ancient rocks: Field and Laboratory, v. 5, no. 2, p. 53-64.

This article attempts to show how underlying structures of meteorite craters might be preserved and to evaluate the meteoritic hypothesis as an explanation for the Flynn Creek, Sierra Madera, and Vredefort structures, previously designated as cryptovolcanic.

19 —— 1938, Established and supposed examples of meteoritic craters and structures: Field and Laboratory, v. 6, no. 2, p. 44-56.


Cryptovolcanic structures, as a structural type, are "characterized by a nearly circular outline; a central uplift with intense structural derangement; and a marginal, ring-shaped depression with irregular and local faulting. Evidence of explosive action is seen in the intensely disordered structure and local brecciation of the central, uplifted portion; the presence (in two of the structures described) of peculiar fracture patterns, the 'shatter cones' and the presence and character of folding in the marginal zone." The structures are thought to be the result of a sudden liberation of pent-up volcanic gases.


22 —— 1963b, Cryptoexplosion structures caused from without or from within the Earth? ("astroblemes" or "geoblemes"): Am. Jour. Sci., v. 261, no. 7, p. 597-649.

Bucher reviews and evaluates developments in the cryptovolcanic-meteoritic hypothesis, with application to the Ries, Wells Creek, and Vredefort problems.


This report details work in progress by C. S. Beals and colleagues, of the Dominion Observatory, Ottawa.
DISTRIBUTION AND CHARACTERISTICS OF STRUCTURES

Ref.
This paper compares New Quebec, Clearwater Lakes, and Manicouagan and notes that none of the craters can be explained by the classical impact theory or by analogy with known volcanic areas.
The presence of shatter cones at Sierra Madera, Flynn Creek, and Serpent Mound is reviewed.
“This newly coined word refers to ancient scars left in the earth’s crust by huge meteorites. The evidence for such impacts is largely the high-pressure mineral coesite and ‘shatter cones’ in the rocks.”
38 ———1963a, Astroblemes, ancient meteorite-impact structures on the Earth, in Middlehurst, Barbara, and Kuiper, G. P., eds., The Moon,
Ref.


Dietz makes a case for shatter cones as a criterion for recognition of the formation of certain geologic structures by intense shock.


The author replies to the objections of W. H. Bucher (ref. 22) and discusses his objections to the concept that cryptoexplosion structures such as the Steinheim and Wells Creek type are “astroblemes.”


Goguel proposes an alternate theory to that of Bucher (ref. 22) and Dietz (ref. 39). “If the hydraulic pressure of water and other fluids contained in a permeable formation should locally exceed the lithostatic pressure, the overlying strata would be lifted into an arch, but the fluid would rapidly escape and the arch would then collapse, producing the chaotic structure and the shatter cones observed.”


50 Halliday, Ian, and Griffin, A. A., 1964, Application of the scientific method to problems of crater recognition: Meteoritics, v. 2, no. 2, p. 79–84; reprinted in Ottawa Dominion Observatory Contr., v. 4, no. 10, p. 79–84.


This work briefly summarizes information on 12 craters.
Ref.


55 Heide, Fritz, 1933a, Meteoritenkrater [Meteorite craters]: Forschung u. Fortschr., v. 9, no. 26, p. 379-381.


Gravity data were used to calculate the mass deficiency and hence the amount of shattered rock under the Deep Bay, Brent, and Holleford Craters.

62 ———1964, Recent advances in meteoritic research at Dominion Observatory, Ottawa, Canada: Meteoritics, v. 2, no. 3, p. 219-242.


Ref.


In a short chapter on crater-producing meteorites, Krinov relates the problem of craters to the bigger problem of meteoritics.


Krinov discusses two types of meteorite craters (explosion and impact); he defines 14 structures as authentic craters, 10 as probable ones.


Eleven craters are given as “authentic.”

78 Ley, Willy, 1937, How the moon got its craters—Experiments duplicate the scars on the face of the moon and support the evidence yielded by the earth's own meteor craters: Nat. History, v. 39, no. 4, p. 275–279.


McCall rejects Dietz's impact hypothesis, and adds arguments to support Bucher's interpretation of the Vredefort and other structures.

DISTRIBUTION AND CHARACTERISTICS OF STRUCTURES

Ref.


This is a concise review of the development of scientific acceptance of the meteoritic theory and of opinion on eight craters currently believed to be meteoritic in origin.


Taking the Barringer crater with its meteoric fragments as an example, Öpik reviews the physical conditions prevailing at high-velocity impact of a solid projectile into a solid surface.


Öpik has received letters citing craters in Maputaland, Northern Zululand; on North Andaman Island, Bay of Bengal (?); near Fairplay, Colo.; in New Mexico, near the Arizona border; and 112 km east of Winslow, Ariz.


Thirty-eight sites are mentioned here, with bibliographic detail.


This summary is intended to help systematize the recognition and investigation of terrestrial impact structures and to serve as a guide to sources of data for the nonspecialist. Tables listing structures by type and an index map to location are included.


In one of the earliest surveys of meteorite craters as a geological problem, Spencer discusses eight examples, five of which he concludes to be meteoritic.


Washburne replies to Boon and Albritton (ref. 17).
DISTRIBUTION AND CHARACTERISTICS OF STRUCTURES


IMPACT SITES

AL HADIDA CRATERS, SAUDI ARABIA

(See Wabar Craters)

AL UMCHAIMIN CRATER, IRAQ

(Lat 32°50' N.; long 39°50' E. Category 5)


Merriam tentatively attributes the origin of this extensive, nearly circular depression to meteoritic impact rather than to solution processes, wind erosion, or volcanism.

AMAK ISLAND CRATER, ALEUTIAN ISLANDS, ALASKA

(Lat 55°44' N.; long 163°09' W. Category 6)


Letters from Charles Keenan, of the U.S. Army, describe a crater on Amak Island ; LaPaz, interested in a program to search for new meteorite craters by air, speculates on the effectiveness of such a program.

AMGUID CRATER, ALGERIA

(Lat 26°31' N.; long 5°21' E. Category 6)

112 Karpoff, Roman, 1953, The meteorite crater of Talemzane in southern Algeria (CN=±0041,333) : Meteoritics, v. 1, no. 1, p. 31-38.

AOUELLOUL CRATER, MAURITANIA

(Lat 20°15' N.; long 12°41' W. Category 2)


Five structures are discussed (Aouelloul, Temimichat-Ghallaman, Tenoumer, Richât, and Semsiyât) ; Aouelloul is considered the only probable meteorite crater.
TERRESTRIAL IMPACT STRUCTURES—A BIBLIOGRAPHY

Ref.


Fragments of silica glass found in and near the crater are considered the products of fusion of meteoritic material. Chemical analyses are included.

See also ref. 73.

ARNHEM LAND CRATER, NORTHERN TERRITORY, AUSTRALIA
(Lat 13°10' S.; long 135°40' E. Category 5)


See also ref. 89.

ASHANTI CRATER, GHANA
(See Lake Bosumtwi)

BAGHDAD CRATERS, IRAQ
(Lat 33°20' N.; long 44°25' E. Two craters. Category 6)


BARRINGER CRATER, COCONINO COUNTY, ARIZ.
(Alternate name: Meteor Crater. Lat 35°02' N.; long 111°01' W. Category 1)


In this paper Barringer refutes the steam explosion theory for the origin of Meteor Crater, as accepted by Gilbert (ref. 162), and details his reasons for supporting a meteoritic hypothesis. This conviction, further stated in supplementary articles (refs. 123, 124), was aided by W. F. Magie (ref. 197) and B. C. Tilghman (ref. 249).
BARRINGER CRATER, ARIZONA

Ref.

122 Barringer, D. M., 1909, Meteor Crater (formerly called Coon Mountain or Coon Butte) in northern central Arizona: Published privately, 24 p., 18 pls.


A theoretical study was made of the cratering process accompanying the impact of a 12,000-ton iron projectile on a semi-infinite half space of soft rock at a velocity of 30 kilometers per second, the constituents and velocity approximating those involved in the formation of Meteor Crater. Bjork concludes that the meteorite had a mass between 30,000 and 194,000 tons, the range being due to uncertainty concerning the impact velocity.


The author estimates the age of Meteor Crater at 40,000 to 75,000 years.

24  TERRESTRIAL IMPACT STRUCTURES—A BIBLIOGRAPHY

Ref.


Stishovite, a recently synthesized high-density polymorph of SiO₂, has been identified in the coesite-bearing Coconino Sandstone of Meteor Crater.


The natural occurrence of coesite has an important bearing on the recognition of meteorite impact craters in quartz-bearing geological formations.


Fairchild concludes that the Barringer meteorite was a large stony mass, with metallic inclusions.


Fairchild concludes that the Barringer meteorite was a large stony mass, with metallic inclusions.


Fairchild concludes that the Barringer meteorite was a large stony mass, with metallic inclusions.


A classic, this paper provides the first detailed geological description of the Arizona crater.


In a telegram to the San Francisco Examiner, Tuesday, December 1, 1891, Gilbert and Baker describe the first examination of Meteor Crater and the finding of meteoric iron.
Ref.


The writer finds the crater and the mound to be two separate, but interrelated, geologic features and supports a geologic, rather than meteoritic, origin for the mound.


Ref.


Crater dimensions derived from the high explosive experience of the Plowshare program are used to estimate equivalent depths of burst and energies of the Arizona and New Quebec Craters.


183 —— 1911, Volcanic phenomena of Coon Butte region, Arizona [abs.]: Iowa Acad. Sci. Proc., v. 18, p. 99-100; also in Science, new ser., v. 34, no. 862, p. 29.


TERRESTRIAL IMPACT STRUCTURES—A BIBLIOGRAPHY

Ref.
194 Lewis, W. S., 1946, Origin of the crater: Desert Mag., v. 9, no. 11, p. 29.

195 Longwell, C. R., 1931, Meteor Crater is not a limestone sink: Science, new ser., v. 73, no. 1887, p. 234–235.


203 ——— 1909, Coon Butte or Meteor Crater [abs.]: Science, new ser., v. 29, no. 736, p. 239–240.


Ref.


Ref.


This paper, with its attendant discussions, represents a difference of opinion with Dorsey Hager. (See ref. 168.)


Nininger describes researches and surveys made since the discovery of the crater and critically reviews findings to date.


The object of this survey was to systematically investigate distribution of minuscule bits of material scattered through the mantle of soil surrounding the crater, with a view to fixing more closely the mass of the meteorite and the direction of its flight.


Ref.


"Studies of craters formed by detonation of nuclear devices at shallow depth in alluvium show that structures of the crater rims are related to the depth of explosion and the yield of the device. The penetration mechanics for Meteor Crater, Arizona, are derived by scaling relationships from nuclear explosion craters, based on detailed geologic mapping of both types of craters."


This paper reverses the usual procedure of attacking the cratering problem on theoretical grounds and applying the results to Meteor Crater by deducing requirements for theory from the geology of the crater and its structural similarity to a nuclear explosion crater.


244 Stutzer, Otto, 1936a, Der Meteor-Krater in Arizona [The meteor crater in Arizona]: Natur und Volk, v. 66, no. 9, p. 442-453.


246 Thomas, Kirby, 1924, Exploring in Arizona for a super meteorite: Arizona Mining Jour., v. 8, no. 4, p. 16.


TERRESTRIAL IMPACT STRUCTURES—A BIBLIOGRAPHY

Ref.


Wylie, using data from explosion and World War I mine craters, proposes a meteorite 35 to 50 feet in diameter, with a mass of 5,000 to 15,000 tons.

257 —— 1943c, Second note on the probable mass of the object which formed Meteor Crater: Pop. Astronomy, v. 51, p. 158-161.


Aerial photographs show Meteor Crater to be square, with rounded corners.

See also refs. 38, 82, 87, 100.

BASRA CRATER, IRAQ
(Lat 30° N.; long 47° E. Category 6)

See ref. 57.

BOXHOLE CRATER, NORTHERN TERRITORY, AUSTRALIA
(Lat 22°37′ S.; long 135°12′ E. Category 1)


The Boxhole Crater was discovered in June 1937. No impactite was found; iron fragments found closely resemble those from the Henbury Crater.
CAMPO DEL CIELO CRATERS, ARGENTINA

Ref.


See also ref. 73.

BRENT CRATER, NIPISSING COUNTY, ONTARIO

(Lat 46°04' N.; long 78°29' W. Category 4)


Brent Crater was first observed on aerial photographs as a circular depression approximately 2 miles in diameter. Geological, magnetic, and seismic investigations lead the authors to conclude that the crater was formed by meteorite impact, possibly in late Precambrian time, and that its present state is a consequence of subsequent erosion and deposition within it of Paleozoic sediments.

See also refs. 14, 31, 64.

CAMPO DEL CIELO CRATERS, CHACO, ARGENTINA

(Lat 27°40' S.; long 61°40' W. Category 1)


This is a detailed history of early explorations.


This is a preliminary report on the 1962 expedition which made the first detailed examination of the Campo del Cielo meteorite field.


Nágera describes and includes photographs of four craters which he believed to be artificial excavations.

267 Parish, Woodbine, 1833, Notice as to the supposed identity of the large mass of meteoric iron now in the British Museum, with the celebrated Ottumpa iron described by Rubin de Celis in the Philosophical Transactions for 1786: Royal Soc. London Philos. Trans., v. 128, p. 53-54.

See also refs. 73, 100.

CAROLINA BAYS, SOUTHEASTERN COAST UNITED STATES

(Lat 33°45' N., long 78°45' W. (center of area). Category 5)


MacCarthy presents six conclusions from a University of North Carolina survey. He feels that the Carolina Bays were formed by shock waves accompanying the meteorite shower and that the meteoritic materials were mostly volatilized. An analogy is made to the 1908 Tunguska event.


This is the first suggestion of a cosmic origin for the bays; the authors propose a theory involving impact by a large cluster of meteorites.


TERRESTRIAL IMPACT STRUCTURES—A BIBLIOGRAPHY

Ref.
   This is the final article of a series in which Prouty develops a modified meteoritic theory for the origin of the Carolina Bays.

CARSWELL LAKE STRUCTURE, SASKATCHEWAN
(Lat 58°27'N.; long 109°30' W. Category 6)

See ref. 14.

The authors point out that this structure shows the kind of deformation expected for a meteorite crater formed in sedimentary rock.
   In describing the general geology of the Carswell formation, Fahrig tentatively classifies the lake feature as a "cryptovolcanic" structure.

See also refs. 13, 65.
CLEARWATER LAKES, QUEBEC

CAVE SPRING HOLLOW, TENN.

(See Wells Creek area)

CHINGE SITE, TUVA AUTONOMOUS REGION, U.S.S.R.

(Lat 51° N.; long 94° E. Category 6)

Ref.

See ref. 73.

Krinov lists the Chinge site as a "probable meteorite crater," although no crater or traces of it have been found. He draws attention to the original shape of the meteorite samples.


CHUBB CRATER, QUEBEC

(See New Quebec Crater)

CLEARWATER LAKES, QUEBEC

(Lat 56°10' N.; long 74°20' W. Two craters. Category 2)


Clearwater Lakes consist of two circular depressions located on a highland of Precambrian granitic gneiss. Geological evidence suggests that the lakes are of volcanic-tectonic origin; the structure of the islands suggest that they represent volcanoes, formed by extrusion of lava along a circular fracture, probably concurrent with caldera collapse.


During a 1958 gravity survey east of Hudson Bay, a Dominion Observatory party collected unusual metamorphic rocks on islands in Clearwater Lakes; they consider these rocks to be the product of meteorite impact.


See also refs. 14, 29.
38  TERRESTRIAL IMPACT STRUCTURES—A BIBLIOGRAPHY

CRATER ELEGANTE, SONORA, MEXICO

(Lat 32°49' N.; long 112°55' W.  Category 5)

Ref.

CRESTONE CRATER, SAGUACHE COUNTY, COLO.

(Alternate name: San Luis Maria Baca Grant Crater. Lat 38°52’ N.; long 105°39’ W.  Category 5)

See ref. 3.

CROOKED CREEK STRUCTURE, CRAWFORD COUNTY, MO.

(Lat 37°50’ N.; long 91°23’ W.  Category 4)


The authors detail evidence which suggests that the Crooked Creek disturbance originated from a subterranean gaseous explosion.

See also ref. 13.

DALGARANGA CRATER, WESTERN AUSTRALIA

(Lat 27°45’ S.; long 117°05’ E.  Category 1)

325  Huss, G. I., 1962, Australia’s Dalgaranga crater: Mineralogist, v. 30, no. 9/10, p. 4–7; no. 11/12, p. 12–14, 16.

This article, together with the Nininger and Huss report (ref. 327), describes the first scientific examination of the Dalgaranga Crater. The unusual character and variety of structures hitherto unknown in connection with other meteorite craters is discussed. The meteorite is judged to be largely stony; the age of the crater is estimated to be 25,000 years.
DEEP BAY, REINDEER LAKE, SASKATCHEWAN

Ref.


328 Simpson, E. S., 1938, Some new and little-known meteorites found in Western Australia: Mineralog. Mag. [London], v. 25, no. 163, p. 157-171.

This report, based on observations of G. E. Willard of the Dalgaranga Station, became the basis for the description of the Dalgaranga Crater and meteorite.

See also ref. 73.

DECATURVILLE DISTURBANCE, CAMDEN COUNTY, MO.
(Lat 37°54' N.; long 92°43' W. Category 4)


"The tectonic history and the presence of the pegmatite(s) appear to support the conclusion that the Decaturville disturbance may be caused by polygonal or ring tectonic movements in the basement, connected with or caused by igneous activity."


See also refs. 2, 26, 321.

DEEP BAY, REINDEER LAKE, SASKATCHEWAN
(Lat 56°24' N.; long 103°00' W. Category 6)


Deep Bay, the southeastern part of Reindeer Lake, is a circular depression with an average diameter of about 8½ miles and a depth, from highest point on the rim to lake bed, of about 1,130 feet. Evidence strongly suggests that it was formed by explosion.


"Topographical, geological and geophysical studies, combined with the results of diamond drilling strongly indicate an origin by meteoritic impact, and lend no support to the thesis that the Deep Bay depression is geologically or structurally controlled."

See also refs. 6, 14, 64, 65.

**DES PLAINES DISTURBANCE, COOK COUNTY, ILL.**

(Lat 42°02' N.; long 87°56' W. Category 6)


The Des Plaines disturbance is here called a "cryptoexplosion structure" —a term implying no specific explosion mechanism. Drilling of wells has yielded data about structural movement which, with information of a negative gravity anomaly, lead the authors to suggest that the disturbance is the "root" of an old impact structure.


**DUCKWATER CRATER, NYE COUNTY, NEV.**

(Lat 38°50' N.; long 115°50' W. Category 5)


A crater, 225 feet in diameter and from 10 to 15 feet deep, was investigated. The authors found no meteoritic material but cannot ascribe origin of this crater to a nonimpact cause.

See also ref. 97.

**DYCUS DISTURBANCE, JACKSON COUNTY, TENN.**

(Lat 36°22' N.; long 85°45' W. Category 6)

See ref. 97.

Shoemaker and Eggleton include this structure in their study primarily on evidence presented by R. M. Mitchum, Jr., in an M.S. thesis, Vanderbilt University, 1961. Actually, Mitchum finds difficulty with both cryptovolcanic and meteoritic hypotheses.
FLYNN CREEK STRUCTURE, TENNESSEE

DZIOUA CRATERS, ALGERIA
(Lat 33°19' N.; long 5°17' W. Category 6)

Ref. See ref. 120.

ELLEF RINGNES ISLAND CRATERS, NORTHWEST TERRITORIES, CANADA
(Lat. 78°30' N.; long 102°30' W. Four craters. Category 6)


EYRE PENINSULA CRATERS, SOUTH AUSTRALIA
(Lat 34° S.; long 136° E. Category 5)

See ref. 89.

FAUGÈRES CRATERS, FRANCE
(See Hérault Craters)

FLYNN CREEK STRUCTURE, JACKSON COUNTY, TENN.
(Lat 36°17' N.; long 85°40' W. Category 4)


This and the following are preliminary reports on fieldwork in progress.


345 Wilson, C. W., Jr., and Born, K. E., 1936, The Flynn Creek disturbance, Jackson County, Tennessee: Jour. Geology, v. 44, no. 7, p. 815-835.

Data accumulated on this small, intensely disturbed area indicate a cryptovolcanic origin.

See also refs. 18, 20, 36.
TERRESTRIAL IMPACT STRUCTURES—A BIBLIOGRAPHY

FRANKTOWN CRATER, ONTARIO
(Lat 45°03' N.; long 76°04' W. Category 5)

Ref. See ref. 14.
Drilling results have substantially eliminated a meteoritic origin for the Franktown Crater.

GLASFORD STRUCTURE, PEORIA COUNTY, ILL.
(Lat 40°35' N.; long 89°49' W. Category 4)
The authors interpret this dome, about 2½ miles in diameter, to be an astrobleme.

GLOVER BLUFF STRUCTURE, MARQUETTE COUNTY, WIS.
(Lat 44°11' N.; long 89°22' W. Category 6)
This is the rewrite of an M.S.'s thesis which Ekern presented to the University of Wisconsin in 1928. Origin of the Glover Bluff structure remains unsettled.

GULF OF ST. LAWRENCE ARC, CANADA
(Lat 47°06' N.; long 63°03' W. Category 6)
The program described here was part of an organized search for craters in the Canadian Shield. The survey found dimensions of the gulf to be consistent with the meteorite explosion hypothesis but found no striking geologic evidence of an explosion.
See also ref. 14.

GWARKUH CRATER, BALUCHISTAN, IRAN
(Lat 28°30' N.; long 60°40' E. Category 5)
The author relates how he was shown the crater first in 1916. At that time it measured 150 feet long, 120 feet wide, and 50 feet deep.

HAVILAND CRATER, KANSAS

Ref.

See ref. 100.

Spencer has examined writings and photographs of Dyer (ref. 349) and Skrine (ref. 351) and does not consider this feature a likely meteorite crater.

HAGENS FJORD CRATERS, GREENLAND

(Lat 81°45' N.; long 28°15' W. Category 6)


HAVILAND CRATER, KIOWA COUNTY, KANS.

(Lat 37°35' N.; long 99°10' W. Category 1)


These notes supplement Nininger and Figgins (ref. 359).


Meteorites were first discovered in the Haviland area in 1885, and subsequently examined by Kunz (ref. 356), Winchell and Dodge (ref. 360), and Hay (ref. 353). Nininger first drew attention to the crater in 1925; here he and Figgins discuss distribution of fragments within the crater.

212-459-66—4
Ref.


See also ref. 73.

HEBRON CRATER, LABRADOR
(see Merewether Crater)

HENBURY CRATERS, NORTHERN TERRITORY, AUSTRALIA
(Lat 24°34' S.; long 133°10' E. Thirteen craters. Category 1)


This article reports the first scientific expedition to Henbury. Alderman describes the locale and meteoritic material found there, points out similarities and differences between these craters and Meteor Crater, and suggests directions future study should take.


Measurements show the Henbury irons to have a terrestrial age of ≲7000 years.


A magnetic survey of 12 craters is discussed. It appears, from the absence of magnetic anomalies of a type that would arise from large meteorites at likely depth, that the craters were formed by excavating action of an explosive impact.

HERAULT CRATERS, FRANCE

Ref.

371 Spencer, L. J., 1932, Meteoric iron and silica-glass from the meteorite craters of Henbury (central Australia) and Wabar (Arabia), with chemical analysis by M. H. Hey: Mineralog. Mag. [London], v. 23, no. 142 p. 387-404.
“At Henbury there is a much better development of the meteoric iron, while at Wabar the silica-glass predominates.”

See also ref. 73.

HERAULT CRATERS, FRANCE
(Alternate names: Faugères Craters, Le Clot, Montagne Noire.
Lat 43°32’ N.; long 3°08’ E. Six craters. Category 6)

Comparison of five of the six known craters in this region, including Le Clot, with four craters of established meteoritic origin provided insufficient evidence to consider them as impact structures.


Two surveyors report and favor a meteoric origin for six depressions in southern France. The largest, Le Clot, was first noticed on an aerial photograph.


Janssen, an astronomer, finds it reasonable to ascribe origins of Le Clot and the Faugères crater to fragments from one meteorite. He includes here a translation of the Gèze-Cailleux article previously cited (ref. 375).
Ref.


HOLLEFORD CRATER, LANARK COUNTY, ONTARIO
(Lat 44°47' N.; long 76°30' W. Category 2)


383 ——— 1960, A probable meteorite crater of Precambrian age at Holleford, Ontario: Ottawa Dominion Observatory Publ., v. 24 no. 6, p. 117-142.

Studies of aerial photographs and seismic and diamond-drill data indicate a circular depression with a depth and profile close to those predicted for a meteorite crater of the observed diameter. Below the Paleozoic sediments which fill the crater are several hundred feet of shattered, pulverized rock for which the only adequate explanation is meteorite impact and explosion. The crater is dated at about 500,000,000 years.


Discovery of the New Quebec Crater stimulated Canadian interest in searching aerial photos for other craters in the Canadian Shield. This reports finding the Holleford Crater and preliminary reasons for suspecting its meteoritic origin.

See ref. 129.

Nonmeteoric subsurface materials from the Barringer and Holleford Craters are compared.


Coesite discovered in selected drill-core material from the Holleford Crater constitutes the oldest known coesite.


Results of petrographic and geochemical study of three drill cores from the Holleford Crater show no meteoritic material was found; however, results do not refute the meteoritic impact theory.

See also refs. 7, 14, 64.

HOWELL STRUCTURE, LINCOLN COUNTY, TENN.
(Lat 35°15' N.; long 86°35' W. Category 4)


In their summary of events in the Howell area, the authors include “an explosion, blowing out a crater at least 100 feet in depth and 1 mile in diameter, and piling up limestone debris around the crater.” The Howell structure is identified as an example of the cryptovolcanic structures. (See ref. 20.)

HUNGARIAN PLAIN, HUNGARY-ROMANIA
(Lat 47° N.; long 21° E. Category 5)


The author suggests that the Hungarian Plain is a huge meteorite crater, rimmed by the Transylvanian Alps.

See also ref. 89.

ILUMETSÄ CRATERS, ESTONIA
(Lat 57°58' N.; long 27°23' E. Three craters. Category 6)


Three depressions, the largest 50 meters in diameter, are discussed. Extensive explorations disclosed no meteoritic material but small magnetic anomalies. Volcanic origin is discounted.

See also ref. 397.

INDIAN MOUND, TENN.
(See Wells Creek area)

JEPTHA KNOB STRUCTURE, SHELBY COUNTY, KY.
(Lat 38°06' N.; long 85°06' W. Category 4)


"The purpose of this report is to give a detailed description of the stratigraphy, structure, and topography of the Knob and by the observations to test these conclusions of Limney." Limney (ref. 393) had described the disturbed nature of the area.


See also ref. 20.
KA-IMU-HOKU, LANAI, HAWAII
(Lat 20°55' N.; long 156°53' W. Category 6)

Ref.

K. P. Emory wrote in 1924 of a "pit in the sand" on the Island of Lanai called Ka-imu-hoku or "the place where a meteor fell."

KAALIJÄRV CRATERS, SAAREMA ISLAND, ESTONIA
(Alternate name: Ösel Craters. Lat 58°24' N.; long 22°40' E. Seven craters. Category 1)


Aaloe continues a line of investigation initiated by Reinwald and Krinov. In two articles listed here, he reports on partial excavation of crater no. 5.


Ref.
404 Giere, W., 1934, Der Meteoritenkrater von Sall auf Oesel [The Sall meteorite crater on Ösel]: Petermanns Mitt., v. 80, p. 372.


This group of seven craters was investigated in some detail, morphologically and as to content of meteoritic fragments. The largest crater is believed due to an explosion which destroyed the meteorite; the small craters, which contain meteoritic fragments, are to be considered impact craters from members of the same meteorite shower.


In the references given here, Reinwald details his researches on the Kaali järv Craters between 1928 and 1941. In this paper he describes the craters and explains their formation by comparison with similar craters in the United States and Australia.

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417 —— 1938, Der Krater von Sall (Kaali järv), ein Meteorkrater-Feld in Estland [The Sall Crater (Kaali järv), a meteor crater field in Estonia]: Natur und Volk, v. 68, no. 1, p. 16-24.


419 Reinwald, I. A., and Luha, A., 1928, Bericht über geologische Untersuchungen am Kaali järv (Krater von Sall) auf Ösel [Comment on geological investigation of Kaali järv (Sall Crater on Ösel)]: Tartu Univ., Geol.-Inst. Toimetused, no. 11, p. 30-42.


See also refs. 73, 100.

KALKKOP STRUCTURE, SOUTH AFRICA
(Lat 32°30' S.; long 24°35' E. Category 6)


KEELEY LAKE, SASKATCHEWAN
(Lat 54°54' N.; long 108°08' W. Category 6)

See ref. 14.

No real investigation of this feature had yet been done. The diameter of Keeley Lake is given as 8 miles.

KENTLAWN STRUCTURE, NEWTON COUNTY, IND.
(Lat 40°45' N.; long 87°25' W. Category 4)


Discovery of trace amounts of coesite in the St. Peter sandstone of the Kentland structure is cited as evidence of impact origin.

The author speculates on the arrangement of shatter cones as an indication of Kentland as a "root" structure of the crater, formed after the late Paleozoic and eroded before the Pleistocene.


The only known area in Indiana exhibiting intense crustal deformation, covers less than 1 square mile and is believed to result from "crypto-volcanic" activity.

See also ref. 20.

KILMICHAEL STRUCTURE, MONTGOMERY COUNTY, MISS.

(Lat 33°30' N.; long 89°33' W. Category 4)


KÖFELS SITE, ÖTZTAL, AUSTRIA

(Lat 47°13' N.; long 10°58' E. Category 6)


Hammer, Wilhelm, 1937a, Nachtrag zur Kritik der Suesschen Meteorkraterdeutung von Köfels in Nr. 9–10 der "Verhandlungen" [Supplementary note to the critique of the Suess meteor crater interpretation of the Köfels in no. 9–10 of the "Verhandlungen"]: Austria Geol. Bund. Verh., no. 12, p. 268-269.


Quartz grains are partially melted but not dissolved in the matrix glass. The structure at Köfels is compared to a crater produced by a nuclear device detonated under a steep hillside.


The author dates the Köfels event as about 8150 B.C., on the basis of glacial chronology.


This is a detailed exposition of the impact crater hypothesis for Köfels.

**LABRADOR CRATER, LABRADOR**

*(See Merewether Crater)*
LAKE BOSUMTWI, GHANA

LAC COUTURE, QUEBEC
(Lat 60°08' N.; long 75°20' W. Category 6)

Ref.


"The evidence as a whole suggests an ancient and eroded meteorite crater of approximately 12 km diameter, of which the circular fringe of islands and peninsulas represents the remains of the rim, formerly several hundred meters in height."

LAKE BOSUMTWI, GHANA
(Alternate name: Ashanti Crater. Lat 6°32' N.; long 1°23' W. Category 2)


This reports a meeting of the West African Science Association in which the Bosumtwi was the central theme.


Potassium-argon dating of two glasses gives an average value of 1.3±0.3 million years for the crater, suggesting a common origin with the Ivory Coast tektites and an analogy with an earlier proposal for an impact origin of the Ries Crater and moldavites.


448 ——— 1937, The geology of the Bosumtwi caldera and surrounding country: Gold Coast Geol. Survey Bull. no. 8, p. 5–38.


The fourth natural occurrence of coesite was found in a sample of breccia taken from the crater by N. R. Junner. In the first article, the authors give X-ray diffraction data and make a case for impact origin.


The author notes that the only genetic theory which appears to fit all observed facts is origin by meteoritic impact.


Rohleder reports here the discovery of shatter or "percussion" cones in Precambrian quartzite and compares them to cones from the Steinheim Basin, Germany.


Rohleder discusses and ascribes the origin of Lake Bosumtwi to volcanic activity; a comparison with the Rieskessel is made.


See also ref. 100.

LAKE DELLEN, SWEDEN
(Lat 61°50' N.; long 16°45' E. Category 6)


LAKE EL'GYTKHYN, SIBERIA, U.S.S.R.
(Lat 67°30' N.; long 172°30' E. Category 6)


On the basis of detailed petrographic investigation, Nekrasov concludes that this structure is of tectonic, rather than meteoritic, origin.

**LAKE HUMELN, SWEDEN**
(Lat 57°24' N.; long 16°12' E. Category 6)
See ref. 457.

**LAKE MICHIKAMAU, LABRADOR**
(Lat 54°34' N.; long 64°27' W. Category 6)
See ref. 14.
A circular structure about 3½ miles in diameter, with a stratified appearance, may be seen on an aerial photograph of the area.

**LAKE MIEN, SWEDEN**
(Lat 56°25' N.; long 14°55' E. Category 6)
Högbom suggests a comparison between Lake Mien and Meteor Crater.
See also ref. 457.

**LAKE SILJAN, DALARNA, SWEDEN**
(Lat 60°55' N.; long 14°50' E. Category 6)
462 Hedstrom, Herman, 1894, Geologiska notiser från Dalarne [Geological notices from Dalarna]: Geol. Fören. Stockholm Förh., v. 16, no. 6, p. 585-593.
Hedstrom describes dikes of what is apparently pseudotachylite.


**LE CLOT, FRANCE**
(See Hérault craters)

**LONAR LAKE, INDIA**
(Lat. 19°59' N.; long 76°51' E. Category 3)

In this famous paper, Gilbert supports a cryptovolcanic interpretation for Lonar, by drawing a comparison with Meteor Crater, Ariz.

"Lonar Crater is probably a meteorite crater on the basis of morphology and structure but the degree of certainty is less than either Ashanti Crater or the New Quebec Crater." A chronology of opinions about Lonar Lake is given.


MACAMIC LAKE, QUEBEC
(Lat 48°52' N.; long 79°01' W. Category 6)

See ref. 10.

MALHA CRATER, SUDAN
(Lat 15°06' N.; long 26°15' E. Category 5)


LaPaz answers H. H. Nininger (ref. 472) with the information that Dr. L. J. Spencer has referred to this structure as the "explosion volcanic crater of Malha, Sudan."


Sandford, K. S., 1935, Geological observations on the northwest frontiers of the Anglo-Egyptian Sudan and the adjoining part of the southern Libyan desert: Geol. Soc. London Quart. Jour., v. 91, pt. 3, p. 323–381. Sandford points out (p. 360) that the Malha crater is a known volcanic explosion crater.

MANICOUAGAN-MUSHALAGAN LAKES AREA, QUEBEC
(Lat 51°28' N.; long 68°37' W. Category 4)


Geologic studies of the Manicouagan Lake feature indicate a central mountain of igneous origin in an area largely covered by flat-lying lavas of somewhat different character.


See also refs. 14, 29.

MANSON STRUCTURE, CALHOUN COUNTY, IOWA
(Lat 42°35' N.; long 94°31' W. Category 4)


See ref. 14.

MECATINA CRATER, QUEBEC
(Lat 50°50' N.; long 59°22' W. Category 6)

Mecatina is cited as an example of a crater filled with sediments sufficiently consolidated to retain their identity while the surrounding rock suffered severe erosion. An aerial photograph is included.

MELVILLE ISLAND CRATERS, NORTHWEST TERRITORIES, CANADA
(Lat 76°40' N.; long 109°00' W. Two craters. Category 6)

See ref. 339.

MENIHEK LAKE AREA, LABRADOR
(Lat 53°42' N.; long 66°40' W. Two craters. Category 6)

See ref. 14.

Aerial photographs reveal two circular structures which exhibit a stratified appearance somewhat similar to the Holleford Crater.

MEREWETHER CRATER, LABRADOR
(Alternate names: Hebron Crater, Labrador Crater, Wetherbee Crater.
Lat 58°02' N.; long 64°02' W. Category 6)


See ref. 73.

Krinov places this structure—under Hebron, its location name—in the list of "probable meteorite craters."
Ref.

Meen compares this crater with other lake-filled depressions in the vicinity and suggests a meteoritic origin, despite an inconclusive magnetometer survey and lack of meteoritic material.

MERRIWELL LAKE, QUEBEC
(Approx lat 58° N.; long 65° W. Category 6)
See ref. 24.

METEOR CRATER, ARIZ.
(See Barringer Crater)

MIDDLESBORO BASIN, BELL COUNTY, KY.
(Lat 36°37’ N.; long 83°44’ W. Category 4)


Recent geologic mapping, the authors feel, does not substantiate previous theories of a tectonic origin for this basin.


MONTAGNE NOIRE, FRANCE
(See Hérault Craters)

MORASKO CRATERS, POLAND
(Lat 52°29’ N.; long 16°54’ E. Category 6)


Maps and profiles are given for eight craters; the two largest, about 60 meters in diameter, lie in close association with the find sites of several large iron meteorites.

MOUNT DOREEN CRATER FIELD, NORTHERN TERRITORY, AUSTRALIA
(Lat 23° S.; long 133° E. Category 5)


Included here is an aerial photo of a large crater, located in salt-encrusted claypan, in an almost inaccessible area.
NEW MEXICO CRATER, NEW MEXICO

Ref.


Sangster reports that H. H. Nininger has seen the Mount Doreen structure from the air and determined that it is not a meteorite crater.

MURGAB CRATERS, TADZHIKSKOY SSR, U.S.S.R.

(Alternate name: Pamir Craters. Lat 38°05' N.; long 76°16' E. Two craters. Category 6)


This review tells of the existence of two craters in the East Pamir highlands, one reported in 1926, one discovered by the expedition described by A. M. Bacharev (ref. 488).


NASTAPOKA ISLANDS ARC, HUDSON BAY, CANADA

(Lat 57°40' N.; long 80°02' W. Category 6)

See ref. 14.

The striking parallel between this feature and Mare Crisium on the Moon is noted. Further investigation is indicated.

NEBIEWALE CRATER, NORTHERN TERRITORY, GHANA

(Lat 10°35' N.; long 1°40' W. Category 6)


The author suggests that the caldera is of "cryptoplutonic" origin.

NEW MEXICO CRATER, MORA COUNTY, N. MEX.

(Lat 36° N.; long 105° W. Category 6)


A 30-foot crater was observed and photographed in 1948, during an air search for another meteoric fall. Specimens taken from the crater are typically from an explosion crater of recent origin.

NEW QUEBEC CRATER, UNGAVA, QUEBEC

(Alternate names: Chubb Crater, Ungava Crater. Lat 61°17' N.; long 73°40' W. Category 3)


Harrison presents evidence of continental glaciation about the crater, asserting that glaciation has obscured evidence of meteoritic origin; LaPaz and Leonard (ref. 514) maintain further evidence from the crater’s interior is necessary.


NEW QUEBEC CRATER, QUEBEC

Ref.


513 Kretz, Ralph, 1960, Geological observations in northern New Quebec, 34 and 35 (parts of) : Canada Geol. Survey Paper 60-12, 17 p., 1 map.


See ref. 505.


The New Quebec Crater was first sighted and photographed from the air by the U.S. Air Force in 1943; in 1950, a prospector, F. W. Chubb, brought it to the attention of Dr. Meen, Director of the Royal Ontario Museum of Geology and Mineralogy. It was on Meen's 1950 and 1951 expeditions to Ungava, described in the nine references cited here, that most of the early data regarding the feature was secured.


520 —— 1951b, Chubb Crater, Ungava, Quebec: Geol. Assoc. Canada Proc., v. 4, p. 49-59.


Ref.


527 Millman, P. M., 1956, A profile study of the New Quebec Crater: Ottawa Dominion Observatory Pub., v. 18, no. 4, p. 61-82.

Millman finds that the New Quebec Crater agrees well with the standard form of explosion craters of comparable size; he feels that this conclusion strengthens the theory of a meteoritic origin.


530 Polar Times, 1962, Meteoritic origin is seen for craters: Polar Times, no. 55, p. 22.


536 Vega, 1954, Ungava crater and glaciation: Vega, no. 16/17, p. 70.

See also refs. 6, 29, 65, 73, 181, 374, 505.

ODESSA CRaters, ECTOR COUNTY, TEX.

(Lat 31°48' N.; long 102°30' W. Two craters. Category 1)


Arthur B. Bibbins discovered a siderite weighing several pounds near Odessa in 1921. Prompted by a further letter from Bibbins (ref. 540) Barringer investigated; here he likens the Odessa Crater to the Meteor Crater of Arizona.

This is a translation of ref. 537.


Boon, J. D., and Albritton, C. C., Jr., 1939, Possibility of an additional meteorite crater near Odessa, Texas: Field and Laboratory, v. 8, no. 1, p. 11–17.


Evans presents some new maps of the Odessa Craters, along with a history of investigations and new data obtained in 1958 and 1960 drillings.


Nininger voices his conviction that Odessa is a meteorite crater. He mentions magnetometer tests which indicate a sizeable magnetic material buried at about 400 feet.


212-459—66——6

This abstract is the first description of the Odessa structure.


Sellards and Evans were participants in a University of Texas expedition to Odessa between 1929 and 1941. Mapping, sampling, core drilling, and extensive excavations resulted in the discovery of numerous meteorites and several small craters.

See also refs. 73, 365.

**ÖSEL CRATERS, ESTONIA**

*See Kaalijärv Craters*

**PAMIR CRATERS, U.S.S.R.**

*See Murgab Craters*

**PANAMINT CRATER, INYO COUNTY, CALIF.**

(Lat 36°05′ N.; long 117°22′ W. Category 5)


This crater is likely a collapse pit. Results of a more intensive investigation by L. E. Humiston and colleagues of the Naval Ordnance Test Station are forthcoming.

**PARIS (SUCY-EN-BRIE AND ALENTOURS) LAKES, FRANCE**

(Lat 48°56′ N.; long 2°30′ E. Category 6)

See ref. 3.
RICHÂT CRATER, MAURITANIA

PARRY SOUND CRATER, ONTARIO
(Lat 45°22' N.; long 79°55' W. Category 6)

Ref.


Some evidence for the meteoritic origin of this feature, 1.5 miles in diameter, is given.

See also ref. 3.

PATOMSKII CRATER, IRKUTSK OBLAST, U.S.S.R.
(Lat 55°00' N.; long 116°58' E. Category 6)


It is postulated that this crater was formed 150–200 years ago. The presence of a raised rim and a central hillock composed of fragmented bedrock are cited as evidence of explosive origin.


The crater, 86 meters in diameter, is described as having a ring wall and central hill and shattered but not altered rocks.

PILOT LAKE, NORTHWEST TERRITORIES, CANADA
(Lat 60°19' N.; long 111°01' W. Category 6)

See ref. 24.

PRETORIA SALT PAN, SOUTH AFRICA
(Lat 25°30' S.; long 28°00' E. Category 3)


The outstanding features of the Salt Pan are the circular depression and shattered rocks on the bottom of the depression and in the vicinity. Nothing suggests volcanic origin, but the parallelism with a meteor crater is obvious.


RICHÂT CRATER, MAURITANIA
(Lat 21°09' N.; long 11°24' W. Category 2)

Ref.
The author considers the Richât "buttonhole" to be the result of a laccolithic thrust.

See also ref. 113.

RIESKESSEL, BAVARIA, GERMANY
(Lat 48°53’ N.; long 10°37’ E. Category 2)


Ref.


This is a concise history and bibliography of the Ries problem to 1948.


On the basis of potassium-argon dates obtained from seven suevite samples from the Ries and six tektites from Czechoslovakia, it is suggested that the tektites may have originated from the explosion that formed the Ries Crater.


Ref.


Ref.
TERRESTRIAL IMPACT STRUCTURES—A BIBLIOGRAPHY

Ref.


612 ——— 1943, Das ratselhafte Ries [The enigmatical Ries]: Schwaben, no. 251, 16 p.


See ref. 245.

The author contends that the Ries is a meteorite crater, not a crypto-volcanic structure as believed by many.


Evidence on the origin of the "crater" is reviewed. A meteoritic impact, followed by a period of volcanic activity, is suggested.
SERPENT MOUND STRUCTURE, OHIO

Ref.


This is about the first suggestion that the Ries is an impact structure. See also ref. 22.

SAN LUIS MARIA BACA GRANT CRATER, COLO.
(See Crestone Crater)

SAULT AU COCHONS STRUCTURE, QUEBEC
(Lat 49°17' N.; long 70°05' W. Category 6)
See ref. 14.

Plate 11 illustrates this circular feature, 7 miles in diameter, which to date has been examined only on aerial photographs.

SAYAN CRATER, KHAKAS, U.S.S.R.
(Lat 53°45' N.; long 93°10' E. Category 6)


This elliptical crater, partially lake-filled and overgrown with forest, measures 370–400 meters at the major axis, 250–350 meters at the minor axis.

SEMSIYÂT DOME, MAURITANIA
(Lat 21°01' N.; long 11°50' W. Category 5)
See ref. 113.

Monod considers this structure to be, without a doubt, a dome.

SERPENT MOUND STRUCTURE, ADAMS COUNTY, OHIO
(Lat 39°02' N.; long 83°25' W. Category 4)


See ref. 423.

Coesite is reported to have been found in the shatter cones of the Lilley Dolomite of the Serpent Mound structure. See also refs. 20, 27, 36.
SIERRA MADERA STRUCTURE, PECOS COUNTY, TEX.

(Lat 30°36' N.; long 102°55' D. Category 4)

Ref.

See ref. no. 18.

On the basis of P. B. King's interpretation (ref. 627), Boon and Albritton suggest an impact origin for the Sierra Madera and Vredefort structures.


The breccia at Sierra Madera is tentatively identified as a great lens, 1 1/2 miles across and possibly as much as 2,800 feet thick; it may have once underlain a crater two miles in diameter.


King compares the Sierra Madera uplift with the Vredefort dome.


"A geographical traverse across the Sierra Madera 'dome' indicates a negative gravity anomaly of 1 1/2 milligals over the zone of brecciation in the center and a residual positive anomaly of 1 1/2 milligals associated with a positive anomaly of 25X10^-5 oersted to the southeast of the zone of brecciation."


See also ref. 36.

SIKHOTE-ALIN CRATERS, U.S.S.R.

(Lat 46°10' N.; long 134°39' E. 122 craters. Category 1)


These are the definitive volumes on Sikhote-Alin.
SIKHOTE-ALIN CRATERS, U.S.S.R. 73

Ref.


637 —— 1962, Otsenka skorosti padeniya nekotorykh ekzemptyarov Sikhote-Alinskogo meteoritnogo dozhdya [Estimate of the impact velocities of some specimens of the Sikhote-Alin multiple fall]: Meteoritika, no. 22, p. 31-41.


642 —— 1951, Orbit of the Sikhote-Alin meteorite: Meteoritika, no. 9, p. 27-31 [in Russian].


Ref.


655 ——1950a, Form and surface structure of the fusion crust of individual specimens of the Sikhote-Alin iron meteoritic rain: Meteoritika, no. 8, p. 78-99 [in Russian].


657 —— 1952, Results of four years of field work and study of specimens of the Sikhote-Alin iron meteoritic rain: Meteoritika, no. 10, p. 88-99 [in Russian].


This chapter relates the Tunguska and Sikhote-Alin falls to the whole problem of meteoritics.
SIKHOTE-ALIN CRATERS, U.S.S.R.

Ref.


The Tunguska and Sikhote-Alin impacts were witnessed falls. Scientific study of the 1908 Tunguska event was begun 19 years later; Sikhote-Alin was thoroughly investigated and analyzed before 1956. Krinov interprets conditions of fall and meteoritic material gathered from the sites.


This paper records Russian news releases and summarizes important information by E. L. Krinov, before May 1947.


673 Observatory, 1947, A large Russian meteorite: Observatory, v. 67, p. 76.


Ref.


682 ——— 1956, O primesyakh v nekotorykh Sichote-Alinskogo zheleznogo meteorita [Impurities in some minerals of the Sikhote-Alin iron meteorite]: Meteoritika, no. 14, p. 87–91 [in Russian].


See also ref. 276.

SOCOTRA CRATER, SOCOTRA
(Lat 12°36' N.; long 53°40' E. Category 5)

Moore reports correspondence, and one photograph, from a Mr. C. Brett who describes having seen this crater in 1942.


STEINHEIM BASIN, BAVARIA, GERMANY
(Lat 48°02' N.; long 10°04' E. Category 3)

In this article the authors coin the word “cryptovolcanic” to designate a structure type.

See ref. 590.
The author offers evidence that the Steinheim Basin and the Ries are not meteor craters but are of volcanic origin.
Ref.


Kranz describes the deposits of the Steinheim Basin and advocates an explosive origin for this cryptovolcanic structure.


689 Silbiger, A., and Weiser F., 1951, Das Steinheimer Becken [The Steinheim Basin]: Meteorbeobachter, 1951, no. 8, p. 3.

See also refs. 235, 559, 616.

SUDBURY BASIN, ONTARIO
(Lat 46°30' N.; long 81°01' W. Category 6)

690 Dietz, R. S., 1962, Sudbury structure as an astrobleme [abs.]: Am. Geophys. Union Trans., v. 43, no. 4, p. 445–446.


The Sudbury structure is interpreted as a 1.7-billion-year-old asteroid impact structure or "astrobleme," and the terrestrial analog of a lunar mare.


TALEMZANE CRATER, ALGERIA
(Lat 33°20' N.; long 4°00' E. Category 3)


See ref. 112.

No meteoritic material has been found in this vicinity. The author reviews and rejects several nonimpact theories of origin.

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TEMIMICHÂT-GHALLAMAN CRATER, MAURITANIA
(Lat 24°15' N., long 9°39' W. Category 6)

Ref.
See ref. 113.
This appears to the author to be an explosion crater.
See also ref. 2.

TENOUNER CRATER, MAURITANIA
(Lat 22°55' N.; long 10°25' W. Category 6)


The fault on which the Tenoumer Crater lies, if prolonged northeast and southwest, lines up with two other known faults of the region, suggesting that they form a single great fault.
See also ref. 113.

TIFFIN CRATER, JOHNSON COUNTY, IOWA
(Lat 41°48' N.; long 91°41' W. Category 5)


TUNGUSKA EVENT, PODKAMMENAYA TUNGUSKA RIVER, SIBERIA
(Lat 60°55' N.; long 101°57' E. Category 5)


A brief resume of previous research is given here, but most attention is directed to new testimony collected between 1928 and 1932 from eyewitnesses and to sound phenomena and meteorological conditions of the day of fall collected from Siberian stations. Character of the explosion and geocentric velocity of the mass is estimated.

703 ——— 1936, New investigation into the fall of a giant meteorite in Siberia on the 30th of June, 1908: Priroda, v. 24, p. 70-72 [in Russian].


706 Bronshten, V. A., 1961, K voprosu o dvizhenii v atmosfere Tungusskogo meteorita [On the problem of the motion of the Tunguska meteorite through the atmosphere]: Meteoritika, no. 20, p. 72–86.


As evidence of cometary nature, Fessenkov cites the radial character of the forest around the fall site, and the abnormally bright nights subsequent to June 30 which could be attributed to small dust particles in the atmosphere.


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80 TERRESTRIAL IMPACT STRUCTURES—A BIBLIOGRAPHY

Ref.

Redondo Beach, Calif., Space Technology Labs., Inc., Translation 71, translated by Z. Jakubski.

Results obtained from processing and analyzing new data are discussed; they appear to support a southeast trajectory for the meteorite. A map drawn in 1961 is included.


718 Ivanov, K. G., 1961, Ob energii vzryva Tungusskogo meteorita [On the energy of the explosion of the Tunguska meteorite]: Meteoritika, no. 21, p. 44-45.


720 Kirova, O. A., 1961, O mineralogicheskom izuchenii prob pochb iz raiona padenlya Tungusskogo meteorita, sobrannykh ekspeditsii 1958 g [Mineralogical study of soil samples collected by the 1958 expedition to the area of fall of the Tunguska meteorite]: Meteoritika, no. 20, p. 32-39.


See ref. 663.

Krinov reviews research made and data collected and again states his preference for the comet theory of origin.


Kulik headed the first expedition, in 1927, to study the Tunguska site, 19 years after the meteorite fall.


Ref.
This is a translation of a paper read in Denver, Colo., 1937.


Whipple was the first to favor a cometary origin for the Tunguska event.


735 Zotkin, I. T., 1961, Ob anomal'nykh opticheskikh yavleniyakh v atmosfere, sryazannykh s nadeniem Tungusskogo meteorita [The fall of the Tunguska meteorite and related optical phenomena in the atmosphere]: Meteoritika, no. 20, p. 40–53.

**TVÄREN BAY, SWEDEN**
(Lat 58°46' N.; long 17°25' E. Category 6)
*See ref. 457.*

**UNGAVA BAY, QUEBEC**
(Lat 60°00' N.; long 67°20' W. Category 6)
*See ref. 13.*

**UNGAVA CRATER, QUEBEC**
*(See New Quebec Crater)*
82 TERRESTRIAL IMPACT STRUCTURES—A BIBLIOGRAPHY

UPHEAVAL DOME, SAN JUAN COUNTY, UTAH
(Lat 38°27' N.; long 109°56' W. Category 5)

Ref.
See ref. 2.
“A highly dissected cryptovolcanic structure with a central dome about 1 1/2 miles across.”

See also ref. 20.

VERSAILLES STRUCTURE, WOODFORD COUNTY, KY.
(Lat 38°02' N.; long 84°45' W. Category 4)


The author describes a circular structure, nearly 1 mile in diameter, with a highly brecciated central dome and a rim structure which might indicate a meteoritic origin.

VREDEFORT STRUCTURE, SOUTH AFRICA
(Lat 27°28' S.; long 27°29' E. Category 4)

The paper reviews some earlier theories of the Vredefort “dome” and the question of centrifugal or centripetal pressure in arching up the central circular region with its flanking ring of overturned sediments.


Daly summarizes five explanations attributing the deformation of the Vredefort to terrestrial forces, then seriously considers the Boon and Albritton suggestion (ref. 18) of a meteorite of asteroid dimensions.

The author suggests that the Vredefort Ring, with its crater diameter of 40 km, is the result of an impact similar in force to that which created Tycho or Copernicus on the Moon.
VREDEFORT STRUCTURE, SOUTH AFRICA

A reply to D. W. Bishopp, ref. 740.


Hargraves finds shatter cones abundant in almost all rocks of the Vredefort area and concludes that the radial orientation of cones found in Witwatersrand quartzites points to a shock locus situated approximately in the center of the ring.


Gravitational anomalies reveal that the Vredefort structure is pear-shaped, its smaller end, the covered portion, pointing to the southeast. Maree uses this information to explain a new theory of origin.


See also refs. 18, 22, 38, 79.
WABAR CRATERS, SAUDI ARABIA

(Alternate name: Al Hadida Craters. Lat 21°30' N.; long 50°28' E. One to four craters. Category 1)

Ref.

This reports the third natural occurrence of coesite, the high pressure polymorph of silica. Wabar is the smallest of three craters where coesite has been found.

759 Halbfass, William, 1933, Ein Meteoritenkrater in Siidarabien [A meteorite crater in Saudi Arabia]: Petermanns Mitt., v. 79, no. 3-4, p. 72.

Of 16 localities in which meteoritic material has been found, only centrally located Al Hadida has craters. This article summarizes investigations made in the Rub' al Khali and adds notes taken from the exploration file of the Arabian American Oil Co.


See also refs. 141, 372.

WELLS CREEK AREA, STEWART COUNTY, TENN.

(Alternate names: Cave Spring Hollow, Indian Mound. Lat 36°23' N.; long 87°40' W. Four structures. Categories 4, 6)

764 Wilson, C. W., Jr., 1953, Wilcox deposits in explosion craters, Stewart County, Tennessee, and their relations to origin and age of Wells Creek Basin structure: Geol. Soc. America Bull., v. 64, no. 7, p. 753-768.
It is concluded that four craters had a common post-Eutaw, pre-Wilcox age and common origin by the impact and resulting explosions of fragments of a meteor. A 2,000-foot core drilled in the center of Wells Creek Basin is summarized.

See also refs. 20, 22.
WOLF CREEK CRATER, AUSTRALIA

WEST HAWK LAKE, MANITOBA
(Lat 49°46’ N.; long 95°12’ W. Category 6)

Ref.


Gravity readings from the lake ice indicate a residual negative anomaly of 6 milligals associated with this feature. The authors suggest an original rim diameter of 12,000 feet, modified by glaciation and erosion.


See also ref. 50.

WETHERBEE CRATER, LABRADOR
(See Merewether Crater)

WILBARGER DOME, WILBARGER COUNTY, TEX.
(Lat 33°50’ N.; long 99°15’ W. Category 6)


Hughes had attributed disturbance in this area to movement of gypsiferous shales; Monnig is convinced that a meteoritic origin is more likely.

WILKES LAND STRUCTURE, ANTARCTICA
(Lat 71° S.; long 140° E. Category 6)


“A meteorite crater in the Wilkes Land region of Antarctica has been postulated as an explanation of the origin of australites. Geophysical data suggest that such a feature may have been located.”


WINKLER CRATER, RILEY COUNTY, KANS.
(Lat 39°29’ N.; long 96°49’ W. Category 6)

See ref. 3.

WOLF CREEK CRATER, WESTERN AUSTRALIA
(Lat 19°18’ S.; long 127°46’ E. Category 1)

Ref.

The Wolf Creek Crater is the second largest crater known to be of meteoritic origin. Its age is here considered to be Pleistocene or Recent.


775 LaPaz, Lincoln, 1954, Meteoritic material from the Wolf Creek, Western Australia, crater (CN=1278,192) : Meteoritics, v. 1, no. 2, p. 200-203.

This report describes two masses of meteoritic material recovered by W. A. Cassidy (ref. 771) and analyzed by the Institute of Meteoritics.


781 Preuss, Ekkehard, 1951, Der Wolf Creek Meteoritenkrater in Westaustralien [The Wolf Creek meteorite crater in Western Australia]: Sternenwelt, v. 3, p. 113.


Reeves, a geologist, was in a party of three who spotted the crater from the air in June 1947. He describes their original theory of volcanic origin and subsequent reasons for change to the impact hypothesis.

See also ref. 73.
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<td>Wethebee Crater</td>
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