Terrestrial Impact Structures— A Bibliography 1965–68

GEOLOGICAL SURVEY BULLETIN 1320

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By JACQUELYN H. FREEBERG

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CONTENTS

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By JACQUELYN H. FREEBERG

ABSTRACT

This bibliography on impact structures supplements U.S. Geological Survey Bulletin 1220 by citing literature published or reviewed since 1964. It adds 17 new structures to the list of 110 previously considered. It is organized in the same manner as Bulletin 1220.

INTRODUCTION

U.S. Geological Survey Bulletin 1220 cited literature published to the end of 1964 and relating to the impact origin of 110 structures; this supplement cites literature published or reviewed since 1964, extends discussion of those structures, and adds 17 new sites to the list.

No attempt is made here to categorize the new structures or redefine the old ones, since there is little new in the way of positive identification and since current definitions of shock phenomena as criteria are adequately summarized elsewhere (Short, refs. 60, 61, 64). The bibliography does effectively eliminate from future consideration three structures: Crestone Crater, Socotra Crater and Ka-imu-hoku. Merriwell Lake is removed, having been a misnomer for Merewether Crater (M. R. Dence, written commun., 1966).

Increasing interest in the problems of cratering and meteoritics has motivated several tallies of craterform structures, notably by Barringer (ref. 4), Monod (ref. 51), and O'Connell (ref. 52). The latter two include sites not mentioned in this bibliography other than in the annotations for the citation; they should not go unmentioned in a list of impact structures, but there is no recent literature on them. Monod's suggestions, based on aerial photographs and his own work in Africa, are mostly yet unstudied in the field; his catalog also includes speculations by Gallant (ref. 37).

This supplement is organized in the same manner as the basic bibliography in Freeberg (ref. 35). However, coordinates are given only for sites introduced into the bibliography for the first time; the list of serial abbreviations supplements that given previously.

SERIALS

The following list supplements that given in U.S. Geological Survey Bulletin 1220, by including form of citation, with complete title, for serials cited here for the first time.

Acad. Royale Belgique Bull. Cl. Sci.—Académie Royale de Belgique, Bulletin de la Classe des Sciences. Brussels, Belgium.

Am. Midland Naturalist—American Midland Naturalist. University of Notre Dame. Notre Dame, Ind.

Astron. Vestnik—Astronomicheskiy Vestnik. Vsesoiuznoe Astronomo-Geodezicheskoe Obshchestvo. Moscow, U.S.S.R.

Australia Bur. Mineral Resources Geology and Geophysics Record—Australia Bureau of Mineral Resources, Geology and Geophysics Record. Canberra, A. C. T., Australia.

Beitr. Mineralogie u. Petrographie—Beiträge zur Mineralogie und Petrographie. Berlin, Germany.

Canada Geol. Survey Prelim. Ser. Map—Canada Geological Survey Preliminary Series Map. Ottawa, Ontario, Canada.

Canadian Jour. Earth Sci.—Canadian Journal of Earth Sciences. National Research Council, Canada. Ottawa, Ontario, Canada.

Canadian Mining and Metall. Bull.—Canadian Mining and Metallurgical Bulletin. Canadian Institution of Mining and Metallurgy. Montreal, Quebec, Canada.

Contr. Mineralogy and Petrology—Contributions to Mineralogy and Petrology. Beiträge für Mineralogie und Petrologie. Berlin, Germany, and New York, N.Y.

Dissert. Abs.—Dissertation Abstracts. Ann Arbor, Mich.

Earth and Planetary Sci. Letters—Earth and Planetary Science Letters. Amsterdam, Netherlands.

Frontiers—Frontiers. A Magazine of Natural History. Academy of Natural Sciences of Philadelphia. Philadelphia, Pa.

Geol. Bavarica—Geologica Bavarica. Bayerisches Geologischen Landesamt. Munich, Germany.

Geologie en Mijnbouw—Geologie en Mijnbouw. Koninklijk Nederlands Geologisch-Mijnbouwkundig Genootschap. The Hague, Netherlands.

GeoSci. News—GeoScience News. Pasadena, Calif.

Geotektonika—Geotektonika. Akademiya Nauk SSSR Geologicheskiy Institut. Moscow, U.S.S.R.

Icarus—Icarus. International journal of the solar system. Academic Press. New York, N.Y.

Indian Geophys. Union Jour.—Indian Geophysical Union, Journal. Hyderabad, India.

Inst. Français d'Afrique Noire Cat. Doc.—Institut Français d'Afrique Noire Catalogue et Document. Paris, France.

Jour. Geol. Education—Journal of Geological Education. National Association of Geology Teachers. Pinceton, N.J.

Karl-Marx-Univ. Leipzig Wiss. Zeitschr., Math.-Naturw. Reihe—Karl-Marx-Universität, Leipzig, Wissenschaftliche Zeitschrift, Mathematisch-Naturwissenschaftliche Reihe. Leipzig, Germany.

Missouri Div. Geol. Survey and Water Resources Rept. Inv.—Missouri Division of Geological Survey and Water Resources Report of Investigations. Rolla, Mo.

Nature and Sci.—Nature and Science. Published for the American Museum of Natural History by the Natural History Press. Garden City, N.Y.

Neues Jahrb. Mineralogie Monatsh.—Neues Jahrbuch für Mineralogie Monatshefte. E. Schweizerbart'sche Verlagsbuchhandlung. Stuttgart, Federal Republic of Germany.

New York Acad. Sci. Annals—New York Academy of Sciences, Annals. New York, N.Y.

Oberhessischen Gesell. Natur- u. Heilkunde Giessen Ber., Naturw. Abt.—Oberhessischen Gesellschaft für Natur- und Heilkunde zu Giessen, Bericht, Naturwissenschaftliche Abteilung. Giessen, Germany.

Ohio Jour. Sci.—Ohio Journal of Science. Ohio State University and Ohio Academy of Science. Columbus, Ohio.

Rand Corporation Paper—Rand Corporation Paper. Rand Corporation. Santa Monica, Calif.

Soc. Géol. France Bull.—Société Géologique de France, Bulletin. Paris, France.

Sveriges Geol. Undersökning Årsb.—Sveriges Geologiska Undersökning Årsbok. Stockholm, Sweden.

Tectonophysics.—Tectonophysics. Amsterdam, Netherlands.

Tennessee Acad. Sci. Jour.—Tennessee Academy of Sciences, Journal. Nashville, Tenn.

Tennessee Div. Geology Geol. Map—

Tennessee Div. Geology Inf. Circ.—

Tennessee Division of Geology, Geologic Map *and* Information Circular. Nashville, Tenn.

TISCO—Tata Iron and Steel Co. Jamshedpur, India.

U.S. Natl. Aeronautics and Space Adm. Tech. Note—U.S. National Aeronautics and Space Administration Technical Note. Washington, D.C.

Zeitschr. Geophysik—Zeitschrift für Geophysik. Deutsche Geophysikalische Gesellschaft. Würzburg, Germany.

Zhur. Teknicheskoi Fiziki—Zhurnal Teknicheskoi Fiziki. Moscow, U.S.S.R.

BIBLIOGRAPHY

DISTRIBUTION AND GENERAL CHARACTERISTICS OF IMPACT STRUCTURES

Ref.

1 Aitken, F. K., and Gold, D. P., 1968, The structural state of potash feldspar—a possible criterion for meteorite impact?, *in* French, Bevan, and Short, N. M., eds., Shock metamorphism of natural materials: Baltimore, Md., Mono Book Corp., p. 519–530.

Optical properties of K-feldspar from rocks surrounding some cryptoexplosion structures vary from high $2V$ to isotropic, with intermediate stages, and may represent zones of shock and (or) thermal metamorphism. Samples from Brent, New Quebec, Holleford, Lac Couture, Pretoria Salt Pan, and Vredefort are being examined.

2 Amstutz, G. C., 1965, A morphological comparison of diagenetic cone-in-cone structures and shatter cones, *in* Geological problems in lunar research: New York Acad. Sci. Annals, v. 123, art. 2, p. 1050–1056.

Illustrations include cones from Crooked Creek.

Ref.

3 Amstutz, G. C., 1965, Tectonic and petrographic observations on polygonal structures in Missouri, *in* Geological problems in lunar research: New York Acad. Sci. Annals, v. 123, art. 2, p. 876–894.

The geotectonic location of the polygonal patterns of Missouri is that of intersection points of two fault patterns. The Crooked Creek and Decaturville structures fit into the pattern of periodic fault and fold pattern of rigid diapiric structures.

4 Barringer, R. W., 1967, World's meteorite craters ("astroblemes"), Version VII, February 1967: Meteoritics, v. 3, no. 3, p. 151–157.

Tables of 31 meteorite craters, 40 suspected astroblemes, and 12 large fall sites are given here; location, size, and proof or evidence of impact are included.

5 Beals, C. S., 1965, The identification of ancient craters, *in* Geological problems in lunar research: New York Acad. Sci. Annals, v. 123, art. 2, p. 904–914; reprinted in Ottawa Dominion Observatory Contr., v. 6, no. 25, 11 p.

The author discusses difficulties in identifying origins; no single theory can be applied to all circular structures.

6 Beals, C. S., and Halliday, Ian, 1965, Impact craters of the Earth and Moon: Royal Astron. Soc. Canada Jour., v. 59, no. 5, p. 199–216; reprinted in Ottawa Dominion Observatory Contr., v. 4, no. 19, 18 p.; reprinted in 1967, with revisions, in Royal Astron. Soc. Canada Jour., v. 61, no. 5, p. 295–313.

Twelve structures being investigated by the Dominion Observatory team are reviewed.

7 Bohn, Ernst, and Stöber, Werner, 1966, Coesit und Stischowit als isolierte natürliche Mineralien [Coesite and stishovite as isolated natural minerals]: Neues Jahrb. Mineralogie Monatsh., 1966, p. 89–96.

8 Brett, Robin, 1967, Metallic spherules in impactite and tektite glasses: Am. Mineralogist, v. 52, no. 3, p. 721–733.

Spherules from Meteor Crater and Wabar impactites were analyzed with the electron microprobe and compared for nickel and iron content with philippinites and indochinite tektites.

9 Bucher, W. H., 1965, The largest so-called meteorite scars in three continents as demonstrably tied to major terrestrial structures, *in* Geological problems in lunar research: New York Acad. Sci. Annals, v. 123, art. 2, p. 897–903.

The Wells Creek, Ries, and Vredefort structures are so closely associated with deep-seated phenomena that the presence of shatter cones or coesite alone must not be accepted as sufficient evidence for impact.

10 Bunch, T. E., 1966, A study of shock-induced microstructures and solid state transformations of several minerals from explosion craters; Pittsburgh Univ., Pennsylvania, Ph. D. thesis, 175 p.; available from Uni-

Ref.

versity Microfilms, Ann Arbor, Mich.; abstract in 1967 in Dissert. Abs., v. 27, no. 8B, p. 2804B.

Structurally disordered plagioclase and quartz and unique deformation microstructures from explosives craters are considered definitive criteria for shock deformation.

11 Bunch, T. E., Cohen, A. J., and Dence, M. R., 1968, Shock-induced structural disorder in plagioclase and quartz, *in* French, Bevan, and Short, N. M., eds., Shock metamorphism of natural materials: Baltimore, Md., Mono Book Corp., p. 509–518.

Maskelynite, an amorphous solid-state transformation product resulting from shock-induced structural disordering of plagioclase, occurs in the Clearwater Lakes, Manicouagan and Ries Craters, and the Sedan nuclear crater.

12 Bunch, T. E., Cohen, A. J., and Dence, M. R., 1967, Natural terrestrial maskelynite: Am. Mineralogist, v. 52, no. 1, p. 244–253; reprinted in Ottawa Dominion Observatory Contr., v. 7, no. 25, p. 244–253.

Maskelynite is found in rocks of the central peaks of Manicouagan and Clearwater West Lakes.

13 Carter, N. L., 1965, Basal quartz deformation lamellae—a criterion for recognition of impactites: Am. Jour. Sci., v. 263, no. 9, p. 786–806.

Quartz deformation lamellae oriented to the basal (0001) plane have been discovered in specimens from the Vredefort, Barringer, and Clearwater Lakes sites; they provide a definitive criterion for recognition of meteorite impact sites. Planar fractures and cleavages in quartz may also be useful.

14 Carter, N. L., 1967, Impact and impactites: Am. Geophys. Union Trans., v. 48, no. 2, p. 693–696.

15 Chao, E. C. T., 1966, Impact metamorphism, *in* Astrogeologic studies annual progress report, July 1, 1965, to July 1, 1966, pt. B: U.S. Geol. Survey open-file rept., p. 135–168.

Metamorphism in the Wabar, Barringer, Ries, Bosumtwi, and Henbury sites is touched upon; for a published report similar in nature to this, see ref. 17.

16 Chao, E. C. T., 1967, Impact metamorphism, *in* Researches in geochemistry: New York, John Wiley & Sons, Inc., v. 2, p. 204–233.

The increasing degree of impact metamorphism in sandstone around Meteor, Henbury, and Wabar Craters is described. Photomicrographs of a granite gneiss around Ries Basin show various degrees of impact metamorphism. Characteristics of phase transition and mineral reactions are described and tabulated.

17 Chao, E. C. T., 1967, Shock effects in certain rock-forming minerals: Science, v. 156, no. 3773, p. 192–202.

This, a general report on shock metamorphism, includes findings of the author on specimens from the Ries Basin, Lake Bosumtwi, and the Barringer, Henbury, Wabar, and Aouelloul Craters.

Ref.

18 Chao, E. C. T., 1968, Pressure and temperature histories of impact metamorphosed rocks—based on petrographic observations, *in* French, Bevan, and Short, N. M., eds., Shock metamorphism of natural materials: Baltimore, Md., Mono Book Corp., p. 135–158.

Major objectives of the study of meteorite impact metamorphism are outlined; an example of metamorphism is illustrated by a suite of granite gneisses from the Ries.

19 Cohenour, R. E., and Sharp, B. J., 1968, The impact theory—asteroids and the earth-moon system: GeoSci. News, v. 1, no. 3, p. 9–11, 32–34.

20 Currie, K. L., 1965, Analogues of lunar craters on the Canadian Shield, *in* Geological problems in lunar research: New York Acad. Sci. Annals, v. 123, art. 2, p. 915–940.

This paper describes, and speculates on the origin of, some 13 craterlike objects found in the Canadian Shield by Dominion Observatory researchers.

21 Currie, K. L., and Shafiquallah, M., 1968, Geochemistry of some large Canadian craters: Nature, v. 218, no. 5140, p. 457–459.

Rock samples from four locations have been analyzed: East Clearwater, West Clearwater, Carswell, and Manicouagan.

22 Dachille, Frank, Gigl, Paul, and Simons, P. Y., 1968, Experimental and analytical studies of crystalline damage useful for the recognition of impact structures, *in* French, Bevan, and Short, N. M., eds., Shock metamorphism of natural materials: Baltimore, Md., Mono Book Corp., p. 555–570.

Specimen crystals were examined from shatter cones, meteoritic craters, volcanic and metamorphic rocks, atomic and chemical explosion sites, and elsewhere.

23 Dence, M. R., 1965, The extraterrestrial origin of Canadian craters, *in* Geological problems in lunar research: New York Acad. Sci. Annals, v. 123, art. 2, p. 941–969; reprinted in Ottawa Dominion Observatory Contr., v. 6, no. 11, p. 941–969.

The author illustrates the distribution and age of Canadian Shield craters in relation to major tectonic provinces. Brent and New Quebec are discussed as structurally simple craters; Clearwater, Carswell, and Manicouagan, as more complex structures.

24 Dence, M. R., 1968, Shock zoning at Canadian craters—Petrography and structural implications, in French, Bevan, and Short, N.M., eds., Shock metamorphism of natural materials: Baltimore, Md., Mono Book Corp., p. 169–184.

Quartz and feldspars have proved the most useful minerals in establishing zones of deformation ascribed to shock at Canadian craters. Three zones are recognized; possible correlation of the zones with experimental Hugoniot data are discussed.

25 Dietz, R. S., 1965, Astroblemes, lunar craters, and maria, *in* Geological problems in lunar research: New York Acad. Sci. Annals, v. 123, art. 2, p. 895–896.

Ref.

26 Dietz, R. S., 1966, Shatter cones and astroblemes, *in* Transactions of the Lunar Geological Field Conference, Bend, Oregon, August 1965: Portland, Oregon Dept. Geology and Mineral Industries, p. 25–31.

27 Dietz, R. S., 1967, Two new shatter cone sites [abs.]: Meteoritics, v. 3, no. 3, p. 108.

Shatter cones have recently been identified at Gosses Bluff and in the main crater of the Kaalijärv group; thus, the number of known sites is raised to 18.

28 Dietz. R. S., 1968, Shatter cones in cryptoexplosion structures, *in* French, Bevan, and Short, N. M., eds., Shock metamorphism of natural materials: Baltimore, Md., Mono Book Corp., p. 267–284.

Orientation of shatter cones at Kentland, Wells Creek, Crooked Creek, Vredefort, and Sudbury are shown to suggest a centrally located ground zero and (or) direction of shock waves propagated from above. An effort is made to differentiate shatter cones from other types of conical structures.

29 El Goresy, Ahmed, 1968, The opaque minerals in impactite glasses, *in* French, Bevan, and Short, N. M., eds., Shock metamorphism of natural materials: Baltimore, Md., Mono Book Corp., p. 531–554.

Numerous polished sections from Aouelloul, Bosumtwi, Henbury, the Ries, and Wabar impact glasses were studied in detail in reflected light and with the electron microprobe; metallic spherules were found in all but that from Aouelloul.

30 Elston, W. E., 1965, Rhyolite ash-flow plateaus, ring-dike complexes, calderas, lopoliths, and Moon craters, *in* Geological problems in lunar research: New York Acad. Sci. Annals, v. 123, art. 2, p. 817–842.

The possibility that the Mogollon Plateau is of impact origin is tossed out lightly; no serious proposal is made.

31 Engelhardt, Wolf von, Bertsch, W., and Muller, W. F., 1967, Shock induced quartz deformation as indication of meteoritic impact [abs.]: Meteorit. Soc., 30th Ann. Mtg., Moffett Field, Calif., 1967, Program.

32 Englehardt, Wolf von, and Stöffler, Dieter, 1965, Spaltflächen im Quarz als Anzeichen für Einschläge grosser Meteoriten [Cleavage planes in quartz as indication of impacts of large meteorites]: Naturwissenschaften, v. 52, no. 17, p. 489–490.

Flat cleavage planes similar to those described in quartz for other meteorite craters are reported for quartz in inclusions of basement rock in the suevite breccia of the Ries and in a breccia associated with Lake Mien, Sweden.

33 Faul, Henry, 1966, Tektites are terrestrial: Science, v. 152, no. 3727, p. 1341–1345.

Age determinations link the origins of some tektites to specific impact craters on the earth's surface; considered are the cases of Lake Bosumtwi, the Ries Basin, and the Kilmichael structure.

Ref.

34 Findlay, D. C., and Smith, C. H., 1965, Drilling for scientific purposes in Canada: Tectonophysics, v. 2, no. 4, p. 247–257.

35 Freeberg, J. H., 1966, Terrestrial impact structures—a bibliography: U.S. Geol. Survey Bull. 1220, 91 p.

36 French, B. M., 1968, Shock metamorphism as a geological process, *in* French, Bevan, and Short, N. M., eds., Shock metamorphism of natural materials: Baltimore Md., Mono Book Corp., p. 1–18.

37 Gallant, Réne, 1964, The bombarded earth, an essay on the geological and biological effects of huge meteorite impact: London, John Baker, 256 p.

The author presents an unorthodox approach to the theory of impact and speculates on the impact origin of certain arcs (Gulf of Campeche, Mosquito Gulf, arc of the West Indies, arc formed by the south coast of Argentina with the Falkland Islands, and Sea of Japan) and depressions (Randecker Maar, Germany; Lac Bouchet, La Sauvetant; and Confolent [crater], France).

38 Gentner, W., 1966, Auf der Suche nach Kratergläsern, Tektiten und Meteoriten in Afrika [On the search for crater glasses, tektites, and meteorites in Africa]: Naturwissenschaften, v. 53, no. 12, p. 285–289.

Geological and geochronological information on Ivory Coast tektites and the Bosumtwi Crater is compared with that on the Ries Basin.

39 Gentner, Wolfgang, Kleinmann, B., and Wagner, G. A., 1967, New K-Ar and fission track ages of impact glasses and tektites: Earth and Planetary Sci. Letters, v. 2, no. 2, p. 83–86.

The observation that measured ages for moldavites and impact glass from the Ries agree, as do those of Ivory Coast tektites and Bosumtwi Crater impactites, lends support to a terrestrial origin for tektites.

40 Gross, W. H., and Sijpkens, J. P., 1965, Cosmic origin of mineral deposits; Canadian Mining and Metall. Bull., v. 58, no. 633, p. 55–59.

It is suggested that additions of cosmic bodies have materially altered the chemistry of the earth's crust and that impact of large meteorites and asteroids has created zones of weakness in the crust that could be centers of magmatic intrusion and mineralization.

41 Hartmann, W. K., 1965, Terrestrial and lunar flux of large meteorites in in the last two billion years: Icarus, v. 4, no. 2, p. 157–165.

The Canadian Shield is considered as a meteorite counter.

42 Innes, M. J. S., 1967, Crater studies, *in* Canadian Upper Mantle report 1967: Canada Geol. Survey Paper 67–41, p. 172–173.

Evidence for impact origin at 12 craters has been discovered to date. In 1966 studies were concentrated at Deep Bay and West Hawk Lake.

43 Innes, M. J. S., Dence, M. R., and Robertson, P. B., 1968. Recent geological and geophysical studies of Canadian craters, *in* French, Bevan, and Short, N. M., eds., Shock metamorphism of natural materials: Baltimore, Md., Mono Book Corp., p. 339–362.

Besides diamond drilling at West Hawk Lake and Deep Bay in 1965–66, the Canadian team made reconnaissance surveys at Pilot and Nicholson

Ref.

Lakes and found evidence of shock and fusion in the fractured and brecciated gneisses of Pilot Lake and a resemblance to Clearwater Lakes in the morphology of Nicholson Lake.

44 Johnson, G. C., 1965, A mathematical analysis of terrestrial impact craters: University Park, Pennsylvania State Univ., Ph. D. thesis, 142 p.; available from University Microfilms, Ann Arbor, Mich.; abstract in 1966 in Dissert. Abs., v. 27, no. 3B, p. 932B.

45 Kelly, A. O., 1967, Continental drift—Is it a cometary impact phenomena? [revised.]: Carlsbad, Calif., published by the author, 100 p.

Features considered in this discussion include the Vredefort Ring, the Gulf of St. Lawrence arc, and the Nastapoka Islands arc.

46 Kelly, A. O., 1967, Continental drift—Is it a cometary impact phenomenon? [abs.]: Meteorit. Soc., 30th Ann. Mtg. Moffett Field, Calif., 1967, Program.

47 Krinov, E. L., 1966, Giant meteorites; translated from the Russian by J. S. Romankiewicz: New York, Pergamon Press, 397 p.

This book is in the nature of a text on meteorite craters; its special importance is in two chapters detailing exploration on the Sikhote-Alin and Tunguska sites.

48 Lane, F. W., 1965, The elements rage [revised ed.]: Philadelphia, Pa., Chilton Books, 346 p. [originally published 1945].

This book contains a section on meteoroids and their place in the early history of scientific thought.

49 McQueen, R. G., Jamieson, J. C., and Marsh, S. P., 1967, Shock-wave compression and X-ray studies of titanium oxide: Science, v. 155, no. 3768, p. 1401–1404.

A new phase which deverts to rutile above 450°C is suggested as a possible new diagnostic indicator of meteorite impact on the earth's surface.

50 Millman, P. M., 1966, Craters: Meteoritics, v. 3, no. 2, p. 55–57.

Craters, discussed in the broad sense, are defined as roughly circular depressions on the surface of a solid which are formed by a force operating near the crater center.

51 Monod, Théodore, 1965, Contribution à l'établissement d'une liste d'accidents circulaires d'origine météoritique (reconnue, possible ou supposée), cryptoexplosive, etc. [Contribution to the establishment of a list of circular irregularities of meteoritic origin (known, possible or suspected), cryptoexplosive, etc.], [2d ed.]; Inst. Français d'Afrique Noire Cat. Doc., no. 18, 93 p.

In his catalog Monod includes sites known only from aerial photographs and not yet studied in the field or documented in the literature; the following are listed by him but not treated in the present bibliography: Agheir, Mauritania; Bishoftu Craters (or Debba Zeit), Ethiopia; Clayton's Craters (or Libyan Desert Craters), Libya; El Mreiti, Mauritania; Erg Ghech (or Erg Touat), Algeria; Foum Teguentour, Algeria; Gallouédec Crater, Mauritania; Garet el-Lefet, Libya; Gourma, Mali; Guer-

Ref.

rara, Algeria; Matam, Senegal; Mejaouda-NW, Mauritania; Michlifen, Morocco; Tademait, Algeria; Tindouf NE, Algeria.

52 O'Connell, Edna, 1965, A catalog of meteorite craters and related features with a guide to the literature: Santa Monica, Calif., Rand Corporation Paper P–3087, 218 p.

Among the 116 structures included in this catalog are 14 not treated in this bibliography: Afton Craters, New Mexico; Estherville Fall, Iowa; Furnas County fall, Nebraska; Knyahinya fall, Czechoslovakia; Lake Hamilton depressions, Australia; Mora County explosion crater, New Mexico; Mount Darwin glass, Australia; Paragould fall, Arkansas; Perevoz Crater, U.S.S.R.; Piute County explosion pits, Utah; Ubehebe Craters, California; Udzbei Bowl, U.S.S.R.; Weepra Park depressions, South Australia; Wiltshire Crater, England.

53 **Pennsylvania State University, Department of Geochemistry and Mineralogy, 1963–67,** Study of structural and mineralogical significance of meteorite impact sites, including mineral paragenesis, high pressure polymorphs, microfractures and quartz lamellae—semi-annual reports to National Aeronautics and Space Administration on grant No. NSG–473: University Park, Pennsylvania State Univ., v. 1–7.

Structures under study include the Pretoria Salt Pan, Lac Couture, the Vredefort structure, and the New Quebec, Holleford, Mecatina, and Brent Craters.

54 Pokrovskiy, G. I., 1964, Deformatsii gornykh porod v zone meteoritnykh kraterov [Deformation of rocks in the meteor crater zones]: Meteoritika, no. 24, p. 99–107.

55 Roberts, W. A., 1968, Shock crater ejecta characteristics, *in* French, Bevan, and Short, N. M., eds., Shock metamorphism of natural materials: Baltimore, Md., Mono Book Corp., p. 101–114.

56 Robertson, P. B., Dence, M. R., and Vos, M. A., 1968, Deformation in rock-forming minerals from Canadian craters, *in* French, Bevan, and Short, N. M., eds., Shock metamorphism of natural materials: Baltimore, Md., Mono Book Corp. p. 433–452.

Four different groups of regular planar features are identified.

57 Ronca, L. B., 1966, Meteoritic impact and volcanism: Icarus, v. 5, no. 5, p. 515–520.

Impact followed by volcanism is briefly discussed, with mention of Sudbury, Wolf Creek, Clearwater Lakes, Manicouagan, and the Ries.

58 Ryabinin, Yu. N., Rodionov, V. N., and Dremin, A. N., 1964, O vozmozhnosti polimorfnykh prevrashcheniy pri udarnom szhatii [On the possibility of polymorphic transformations upon shock compression]: Meteoritika, no. 24, p. 91–98.

The velocity of the iron meteorite which formed Wabar Crater is used as a model in discussing the transformation of quartz to coesite under shock-wave compression.

Ref.

59 Sclar, C. B., Short, N. M., and Cocks, G. C., 1968, Shock-wave damage in quartz as revealed by electron and incident-light microscopy, *in* French, Bevan, and Short, N. M., eds., Shock metamorphism of natural materials: Baltimore, Md., Mono Book Corp., p. 483–494.

Fracture patterns were studied in quartz from Wabar Craters, Meteor Crater, and the Middlesboro structure.

60 Short, N. M., 1965, A comparison of features characteristic of nuclear explosion craters and astroblemes, *in* Geological problems in lunar research: New York Acad. Sci. Annals, v. 123, art. 2, p. 573–616.

Twenty-seven criteria for recognition of impact structures are tabulated; they are a combination of pertinent features associated with nuclear craters and those already accepted as valid indicators of impact.

61 Short, N. M., 1966, Shock processes in geology: Jour. Geol. Education, v. 14, no. 4, p. 149–166.

Diagnostic features for 43 impact sites are tabulated.

62 Short, N. M., 1967, Astroblemes and meteorite craters, *in* Fairbridge, R. W., ed., Encyclopedia of atmospheric science and astrogeology, Volume 2 *of* Encyclopedia of the earth sciences: New York, Reinhold Press, p. 40–43.

63 Short, N. M., 1967, Explosion craters, *in* Fairbridge, R. W. ed., Encyclopedia of atmospheric science and astrogeology, Volume 2 *of* Encyclopedia of the earth sciences: New York, Reinhold Press, p. 373–378.

64 Short, N. M., and Bunch, T. E., 1968, A worldwide inventory of petrologic features characteristic of rocks associated with presumed meteorite impact craters, *in* French, Bevan, and Short, N. M., eds., Shock metamorphism of natural materials: Baltimore, Md., Mono Book Corp., p. 255–266.

At the conference the authors exhibited a world map on which crater locations were plotted; actual samples from many of the craters; approximately 100 annotated photomicrographs showing textures and microdeformation features typical of rocks taken from the craters; and a tabular chart containing capsule information on field, petrographic, and other studies of these craters.

65 Snyder, F. G., and Gerdemann, P. E., 1965, Explosive igneous activity along an Illinois-Missouri-Kansas axis: Am. Jour. Sci., v. 263, no. 6, p. 465–493.

Eight distinctive geologic events, characterized by intrusive or extrusive igneous activity and (or) intense local deformation, are alined in a 400-mile structural zone trending east-west; among them are the Crooked Creek and Decaturville structures.

66 Snyder, F. G., and others, 1965, Cryptoexplosive structures in Missouri—Guidebook, 1965 Ann. Mtg., Geological Society of America: Missouri Div. Geol. Survey and Water Resources Rept. Inv. 30, 73 p.

Structures visited included Crooked Creek and Decaturville.

Ref.

67 Struve, Otto, 1966, Meteorites and their effects, *in* Neighbors of the Earth—Planets, comets, and the debris of space: New York, Macmillan Co., p. 222–226 [originally published 1959].

68 Walker, W. W., 1967, The effects of shock recrystallization on selected meteoritic minerals [abs.]: Meteorit. Soc., 30th Ann. Mtg., Moffett Field, Calif., 1967, Program.

IMPACT SITES

AGNAK ISLAND CRATERS, NORTHWEST TERRITORIES, CANADA

(Lat. 67°30′ N.; long 108°60′ W. Four craters)

See ref. 20.

AOUELLOUL CRATER, MAURITANIA

69 Chao, E. C. T., Dwornik, E. J., and Merrill, C. W., 1966, Nickel-iron spherules from Aouelloul glass: Science, v. 154, no. 3750, p. 759–760, 765.

Nickel-iron spherules, occurring in discrete bands of siliceous glass enriched in dissolved iron, is significant tangible evidence that both crater and glass originated from terrestrial impact.

70 Chao, E. C. T., Dwornik, E. J., and Merrill, C. W., 1966, Nickel-iron spherules from the Aouelloul glass of Mauritania, Africa, *in* Astrogeologic studies annual progress report, July 1, 1965, to July 1, 1966, pt. B: U.S. Geol. Survey open-file rept., p. 169–180.

71 Chao, E. C. T., Merrill, C. W., Cuttitta, Frank, and Annell, Charles, 1966, The Aouelloul crater and the Aouelloul glass of Mauritania, Africa [abs.]: Am. Geophys. Union Trans., v. 47, no. 1, p. 144.

See also refs. 17, 29.

ARN VALLEY CRATERS, YAKUTSK, U.S.S.R.

(Lat 53° N.; long 138°50′ E.)

72 Shevchenko, V. K., 1964, Sledy padeniya meteorita [Traces of a meteorite fall]: Priroda, 1964, no. 4, p. 98.

A chain of small craters in the Arn Valley, lower Amur area and about 50 kilometers west of Kherpuchi, are reported; no meteorites have been recovered.

BARRINGER CRATER, COCONINO COUNTY, ARIZ.

73 Ayer, N. J., 1966, Possible relationship between color loss in hyacinth zircons and meteoritic impact [abs.]: Geol. Soc. America Spec. Paper 87, p. 193.

74 Beaty, J. J., 1966, The great crater controversy: Frontiers, v. 30, no. 4, p. 112–117.

75 Bennett, M. A., 1967, Exploring Meteor Crater: Pacific Discovery, v. 20, no. 3, p. 11–15.

Ref.

76 Brereton, R. G., 1965, Aeromagnetic survey of Meteor Crater, Arizona, *in* Geological problems in lunar research: New York Acad. Sci. Annals, v. 123, art. 2, p. 1175–1181.

An unusual anomaly is associated with Meteor Crater but cannot possibly be related to a buried mass of extraterrestrial matter.

77 Cook, C. S., 1964, Mass of the Canyon Diablo meteoroid: Nature, v. 204, no. 4961, p. 867; review in Sky and Telescope, v. 29, no. 4, p. 222.

78 Hall, R. A., 1965, Secondary meteorites from the Arizona crater: Meteoritics, v. 2, no. 4, p. 337–348.

79 Heymann, Dieter, Lipschutz, M. E., Nielsen, Betty, and Anders, Edward, 1965, Canyon Diablo meteorite—Metallographic and mass spectrometric study of 56 fragments: Jour. Geophys. Research v. 71, no. 2, p. 619–641; abstract in Am. Geophys. Union Trans., v. 46, no. 1, p. 123.

80 Lipschutz, M. E., 1965, Origin of atypical meteorites from the Arizona meteorite crater: Nature, v. 208, no. 5011, p. 636–638.

81 Mead, C. W., Littler, Janet, and Chao, E. C. T., 1965, Metallic spheroids from Meteor Crater: Am. Mineralogist, v. 50, nos. 5–6, p. 667–681.

The spheroids were studied in detail and found to be nearly identical in texture and assemblages to Philippine and Indochina tektite spherules.

82 Oriti, R. A., 1965, The largest meteoritic diamond: Griffith Observer, v. 29, no. 12, p. 173–175.

A large diamond was found in a 160-gram specimen from the east rim of the crater.

83 Roberts, W. A., 1965, Genetic stratigraphy of the Meteor Crater outer lip: Icarus, v. 4, no. 4, p. 431–433.

The ejecta in the outer lip of Meteor Crater was mapped in units related to the in situ formations in which the crater was formed and subdivided into units correlative with those noted in the Sedan lip to obtain data for prediction on formation and extent of bulk ejecta.

84 Struve, Otto, 1966, The making of the Barringer meteorite crater, *in* Neighbors of the Earth—planets, comets, and the debris of space: New York, Macmillan Co., p. 226–228 [originally published 1959].

85 Weber, R., 1965, Au Meteor Crater [At Meteor Crater]: Astronomie, v. 79, no. 5, p. 179–187.

86 Wilkins, J., Jr., and Sumner, J. S., 1968, An induced polarization survey of Meteor Crater, Arizona [abs.]: Am. Geophys. Union Trans., v. 49, no. 1, p. 272.

See also refs. 8, 13, 15–17, 47, 55, 59.

BASS STRAIT

(Lat 40° S.; long 146° E.)

87 Humiston, L. E., 1967, Bass Strait between Australia and Tasmania proposed as a cometary impact site [abs.]: Meteorit. Soc., 30th Ann. Mtg., Moffett Field, Calif., 1967, Program.

Ref.

BOXHOLE CRATER, NORTHERN TERRITORY, AUSTRALIA

88 Cassidy, W. A., 1968, Descriptions and topographic maps of the Wolf Creek and Boxhole craters, Australia [abs.]: Conference on shock metamorphism of natural materials, April 14–16, 1966, Goddard Space Flight Center, Greenbelt, Md., Program, p. 100.

BRENT CRATER, NIPISSING COUNTY, ONTARIO

89. Currie, K. L., and Shafiqullah, M., 1967, Carbonatite and alkaline igneous rocks in the Brent Crater, Ontario: Nature, v. 215, no. 5102, p. 725–726.

Petrochemistry strongly suggests that the structure is an alkaline carbonatite complex.

90 Gold, D. P., 1968, A study of quartz subfabrics from the Brent crater, Ontario, *in* French, Bevan, and Short, N. M., eds., Shock metamorphism of natural materials: Baltimore, Md., Mono Book Corp., p. 495–508.

Planar features in quartz, from quartzo-feldspathic gneisses which surround the Brent Crater, include microfractures, planar trains of inclusions, lamellae, and extinction planes.

See also refs. 1, 20, 23, 53.

BUTARE CRATER, RWANDA

(Lat 2°36′ S.; long 29°44′ E.)

91 Dehousse, Martin, 1966, L'Entonnoir de Butare au Rwanda [The Butare crater in Rwanda]: Acad. Royale Belgique Bull. Cl. Sci., v. 52, no. 1, p. 76–92.

Observations of nonnegligible anomalies made in the course of a topographic and geologic investigation are discussed.

CAMPO DEL CIELO CRATERS, CHACO, ARGENTINA

92 Ashbee, K. H. G., and Vassamilet, L. F., 1966, Dislocation in a Campo del Cielo meteorite: Science, v. 151, no. 3717, p. 1526–1527.

93 Bunch, T. E., and Cassidy, W. A., 1968, Impact-induced deformation in the Campo del Cielo meteorite, *in* French, Bevan, and Short, N. M., eds., Shock metamorphism of natural materials: Baltimore, Md., Mono Book Corp., p. 601–612.

A possible correlation has been found for intensity of deformation and proximity to the meteorite craters.

94 Cassidy, W. A., 1967, Meteorite field studies at Campo del Cielo: Sky and Telescope, v. 34, no. 1, p. 4–10.

The author was leader of the expedition mentioned in ref. 96. Here he describes further work and discusses some important findings.

95 Cassidy, W. A., 1968, Meteorite impact craters at Campo del Cielo, Argentina, *in* French, Bevan, and Short, N. M., eds., Shock metamorphism of natural materials: Baltimore, Md., Mono Book Corp., p. 117–128.

With some exceptions the craters of Campo del Cielo are believed to be penetration funnels; a surprising number of metamorphic features were found. The external appearance of the reaction zone is not unlike large fragments of highly altered material found at Wolf Creek.

Ref.
96 Cassidy, W. A., Villar, L. M., Bunch, T. E., Kohman, T. P., and Milton, D. J., 1965, Meteorites and craters of Campo del Cielo, Argentina: Science, v. 149, no. 3688, p. 1055–1064.

The authors were members of a field party sponsored by the National Science Foundation to the craters in 1962–63.

97 Öpik, E. J., 1966, The Campo del Cielo group of meteorite craters: Irish Astron. Jour., v. 7, no. 5, p. 169.

Öpik comments on work described in ref. 96.

See also ref. 178.

CARSWELL LAKE STRUCTURE, SASKATCHEWAN

98 Currie, K. L., 1967, Shock metamorphism in the Carswell circular structure, Saskatchewan, Canada: Nature, v. 213, no. 5071, p. 56–57.

Circumstances in which rocks of the Carswell structure exhibiting shock effects were found cast doubt on its impact origin.

See also refs. 21, 23.

CHASSENON CRATER, FRANCE

(Lat 45°51′ N.; long 0°46′ E.)

99 Kraut, François, 1967, Sur l'origine des clivages du quartz dans les brèches "volcaniques" de la région de Rochechouart [On the origin of quartz cleavages in volcanic breccias in the region of Rochechouart]: Acad. Sci. Comptes Rendus, ser. D, v. 264, no. 23, p. 2609–2612.

The volcanic breccias, particularly those of Chassenon, show a great analogy with the suevites from the Ries. Structures in the quartz are generally attributed to shock metamorphism when the breccias formed.

CLEARWATER LAKES, QUEBEC

100 Bostock, H. H., 1965, Clearwater complex, New Quebec: Canada Geol. Survey Paper 64–45, 17 p.

The Clearwater Lakes basin is thought to be of volcanic origin, transitional between cauldron subsidence and cryptoexplosion. The order of emplacement, the petrographic details of the rocks of the complex, and the alteration accompanying them do not support an impact origin.

101 Carter, N. L., 1968, Meteoritic impact and deformation of quartz: Science, v. 160, no. 3827, p. 526–528.

102 Dence, M. R., Innes, M. J. S., and Beals, C. S., 1965, On the probable meteorite origin of the Clearwater Lakes, Quebec: Royal Astron. Soc. Canada Jour., v. 59, no. 1, p. 13–22; reprinted in Ottawa Dominion Observatory Contr., v. 6, no. 7, 10 p.

Gravity observations have indicated negative anomalies of a kind associated with meteorite craters whose subsurface structure is characterized by large volumes of low-density breccia.

103 Engelhardt, Wolf von, Hörz, Friedrich, Stöffler, Dieter, and Bertsch, W., 1968, Observations on quartz deformation in breccias of West Clearwater Lake, Canada, and the Ries Basin, Germany, *in* French, Bevan,

Ref.

and Short, N. M., eds., Shock metamorphism of natural materials: Baltimore, Md., Mono Book Corp., p. 475–482.

104 McIntyre, D. B., 1968, Impact metamorphism at Clearwater Lake, Quebec, *in* French, Bevan, and Short, N. M., eds., Shock metamorphism of natural materials: Baltimore, Md., Mono Book Corp., p. 363–366.

Unusual metamorphic rocks were collected on islands in Clearwater Lake during a 1958 gravity survey.

See also refs. 11–13, 21, 23, 43, 57.

COLLUMA CRATER, BOLIVIA

(Lat 18°32′ S.; long 68°5′ W.)

105 U.S. Geological Survey, 1967, Colluma Crater investigation, *in* Geological Survey research 1967: U.S. Geol. Survey Prof. Paper 575–A, p. A103.

A field party briefly investigated this crater in 1966 without finding recognizable meteorite fragments, impact glass, or volcanic layers. Pending further evidence, it is considered to be a collapsed dome.

CRESTONE CRATER, SAGUACHE COUNTY, COLO.

106 Marvin, U. B., and Marvin, T. C., 1966, A re-examination of the crater near Crestone, Colorado: Meteoritics, v. 3, no. 1, p. 1–10.

Mapping and drilling to a depth of 8 feet show no meteoritic debris, spherules, rock flows, or impact glass. The crater should no longer be considered as of possible impact origin.

CROOKED CREEK STRUCTURE, CRAWFORD COUNTY, MO.

107 Hendriks, H. E., 1965, The Crooked Creek structure, *in* ref. 66: pp. 68–72.

A meteoritic impact origin for Crooked Creek is upheld.

See also refs. 2, 3, 28, 65.

DECATURVILLE DISTURBANCE, CAMDEN COUNTY, MO.

108 Zimmermann, R. A., and Amstutz, G. C., 1965, The polygonal structure at Decaturville, Missouri—new tectonic observations: Neues Jahrb. Mineralogie Monatsh., 1965, nos. 9–11, p. 288–307.

Decaturville dome is most probably associated with the regional structural pattern; repeated crustal movement probably played an important part in its formation.

See also refs. 3, 65, 66.

DEEP BAY, REINDEER LAKE, SASKATCHEWAN

109 Bertaud, C., 1965, Cratère météoritique fossile de la Baie-Profonde [The Deep Bay fossil meteorite crater]: Astronomie, v. 79, no. 8, p. 329–331.

See also refs. 20, 42.

DIRRANBANDI CRATERS, QUEENSLAND, AUSTRALIA

(Lat 28°35′ S.; long 148°10′ E.)

110 Binns, R. A., 1967, Possible meteorite craters near Dirranbandi, Queensland [abs.]: Meteorit. Soc., 30th Ann. Mtg., Moffett Field, Calif., 1967. Program.

Ref.

DZHAUSOV CRATERS, UZBEK, U.S.S.R.

(Lat 39°15′ N.; long 67°15′ E. Two craters)

111 Kravtzev, D. I., 1951, Dzhavsovskii bolid [Dzhausov bolide]: Priroda, v. 40, no. 7, p. 41–43.

Two craters, produced in 1950, are reported in an inaccessible place in the Samarkand Oblast.

FLYNN CREEK STRUCTURE, JACKSON COUNTY, TENN.

112 Roddy, D. J., 1965, Recent geologic and laboratory investigations of the Flynn Creek structure, Tennessee, *in* Astrogeologic studies annual progress report, July 1, 1964, to July 1, 1965, pt. B: U.S. Geol. Survey open-file rept., p. 50–52.

113 Roddy, D. J., 1966, Carbonate deformation at a probable impact crater at Flynn Creek Tennessee [abs.]: Am. Geophys. Union Trans., v. 47, no. 3, p. 493–494.

114 Roddy, D. J., 1966, History and origin of the Flynn Creek crater, Tennessee—final report, *in* Astrogeologic studies annual progress report, July 1, 1965, to July 1, 1966, pt. B: U.S. Geol. Survey open-file rept., p. 1–40.

115 Roddy, D. J., 1966, The Paleozoic crater at Flynn Creek, Tennessee: Pasadena, California Inst. Technology, Ph. D. thesis, 232 p.; available from University Microfilms, Ann Arbor, Mich.; abstract in 1967 in Dissert. Abs., v. 27, no. 5B, p. 1517B–1518B.

116 Roddy, D. J., 1966, Minimum energy of formation for a probable impact crater at Flynn Creek, Tennessee [abs.]: Am. Geophys. Union Trans., v. 47, no. 3, p. 482.

117 Roddy, D. J., 1966, An unusual dolomitic basal facies of the Chattanooga shale in the Flynn Creek structure [abs.]: Am. Mineralogist, v. 51, nos. 1–2, p. 270.

118 Roddy, D. J., 1968, Comet impact and formation of Flynn Creek and other craters with central peaks [abs.]: Am. Geophys. Union Trans., v. 49, no. 1, p. 272.

119 Roddy, D. J., 1968, The Flynn Creek Crater, Tennessee, *in* French, Bevan, and Short, N. M., eds., Shock metamorphism of natural materials: Baltimore, Md., Mono Book Corp., p. 291–322.

Good comparisons can be made between the Flynn Creek structure and chemical, nuclear, and meteorite impact craters, but only poor structural analogies are possible with volcanic explosion craters.

120 Roddy, D. J., 1968, Paleozoic crater at Flynn Creek—a probable impact structure [abs.]: Geol. Soc. America Spec. Paper 101, p. 179.

121 Roddy, D. J., 1968, Shock metamorphism in carbonate rocks at probable impact structures [abs.]: Geol. Soc. America, Cordilleran Sec.; Seismol. Soc. America; Paleont. Soc., Pacific Coast Sec., 64th Ann. Mtg., Tucson, Ariz., 1968 Program, p. 103.

Ref.

FREETOWN COMPLEX

(Lat 8°20′ N.; long 13°20′ W. Off Sierra Leone coast)

122 Krause, D. C., 1963, Seaward extension and origin of the Freetown layered basic complex of Sierra Leone: Nature, v. 200, no. 4913, p. 1280–1281.

Suggestion of an impact origin is based on echo soundings and magnetometer traverses.

GOSSES BLUFF, NORTHERN TERRITORY, AUSTRALIA

(Lat 23°50′ S.; long 132°18′ E.)

123 Cook, P. J., 1966, The Gosses Bluff crypto-explosion structure: Australia Bur. Mineral Resources Geology and Geophysics Record 1966/132, 41 p.

See ref. 124.

124 Cook, P. J., 1968, The Gosses Bluff cryptoexplosion structure: Jour. Geology, v. 76, no. 2, p. 123–139.

Recent drilling and geological mapping have shown Gosses Bluff, with a minimum diameter of 10 miles, to be a central uplifted dome surrounded by a ring of breccia containing well-developed shatter cones and glassy material and quartz grains exhibiting fracturing and strain lamellae. There is more, at the present, to support an extraterrestrial origin than an intraterrestrial one.

125 Crook, K. A. W., 1967, Cosmic ice residuum associated with an astrobleme?: Nature, v. 213, no. 5080, p. 999–1000.

Gases encountered in shallow drill holes may be the remnants of a cometary bolide.

126 Crook, K. A. W., and Cook, P. J., 1966, Gosses Bluff—Diapir, crypto-volcanic structure or astrobleme?: Geol. Soc. Australia Jour., v. 13, pt. 2, p. 495–516.

Gosses Bluff is a cryptoexplosive structure resulting from deep-seated explosive volcanic activity or from meteoric impact sometime during the Mesozoic.

127 Dietz, R. S., 1967, Shatter cone orientation at Gosses Bluff astrobleme: Nature, v. 216, no. 5120, p. 1082–1084; abstract in Meteorit. Soc., 30th Ann. Mtg., Moffett Field, Calif., 1967, Program.

Shatter cones caused by shock fracturing are widely developed at Gosses Bluff; the force field can be reconstructed whereby the applied shock arrived centrally and from above.

128 Milton, D. J., and Brett, Robin, 1968, Gosses Bluff astrobleme, Australia—the central uplift [abs.]: Geol. Soc. America, Cordilleran Sec.; Seismol. Soc. America; Paleont. Soc., Pacific Coast Sec., 64th Ann. Mtg., Tucson, Ariz., 1968, Program, p. 82.

129 Moss, F. J., 1964, Gosses Bluff seismic survey, Amadeus basin, Northern Territory 1962: Australia Bur. Mineral Resources Geology and Geophysics Record 1964/66, 12 p.

See also ref. 27.

Ref.

GULF OF ST. LAWRENCE ARC, CANADA

See ref. 45.

HENBURY CRATERS, NORTHERN TERRITORY, AUSTRALIA

130 Hodge, P. W., 1965, The Henbury meteorite craters: Smithsonian Contr. Astrophysics, v. 8, no. 8, p. 199–201.

This review article discusses scientific work since 1931, describes a probable new crater, and includes a series of 17 aerial and ground photographs.

131 Milton, D. J., 1965, Structure of the Henbury meteorite craters, Australia [abs.] : Geol. Soc. America Spec. Paper 82, p. 266.

132 Milton, D. J., 1968, Structural geology of the Henbury meteorite craters, Northern Territory, Australia, *in* Contributions to astrogeology: U.S. Geol. Survey Prof. Paper 599–C, p. C1–C17.

This report is based on field studies started in 1963; it briefly describes the crater field as a whole but is primarily concerned with the structural geology of the wall and rimcrest areas of the three largest craters.

133 Milton, D. J., 1968, Structure of the Henbury meteorite craters, Australia, *in* French, Bevan, and Short, N. M., eds., Shock metamorphism of natural materials: Baltimore, Md., Mono Book Corp., p. 115–116.

134 Milton, D. J., and Michel, F. C., 1965, Structure of a ray crater at Henbury, Northern Territory, Australia, *in* Geological Survey research 1965: U.S. Geol. Survey Prof. Paper 525–C, p. C5–C11.

135 Taylor, S. R., 1965, Similarity in composition between Henbury impact glass and australites: Geochim. et Cosmochim. Acta, v. 29, no. 5, p. 599–601.

Additional evidence is given toward the view that the present composition of australites reflects that of their parent material.

136 Taylor, S. R., 1966, Australites, Henbury impact glass and subgreywacke—a comparison of the abundances of 51 elements: Geochim. et Cosmochim. Acta, v. 30, no. 11, p. 1121–1136; abstract in 1967 in Meteoritics, v. 3, no. 3, p. 128.

No significant differences in composition between the impact glass and the parental greywackes are seen, and no significant alteration has taken place during melting for the elements studied.

137 Taylor, S. R., 1967, Composition of meteorite impact glass across the Henbury strewnfield; Geochim. et Cosmochim. Acta, v. 31, no. 6, p. 961–968.

138 Taylor, S. R., 1967, Geochemistry of Australian meteoritic impact glasses and tektites (australites) [abs.]: Am. Geophys. Union Trans., v. 48, no. 1, p. 158.

139 Taylor, S. R., and Kolbe, P., 1965, Geochemistry of Henbury impact glass: Geochim. et Cosmochim. Acta, v. 29, no. 7, p. 741–745.

Glass found north of the main crater is analyzed.

See also refs. 15–17, 29.

HOLLEFORD CRATER, LANARK COUNTY, ONTARIO

See refs. 1, 20, 53.

Ref.

JEPTHA KNOB STRUCTURE, SHELBY COUNTY, KY.

140 Seeger, C. R., 1966, Origin of the Jeptha Knob structure, Kentucky: Pittsburgh Univ., Pennsylvania, Ph. D. thesis, 152 p.; available from University Microfilms, Ann Arbor, Mich.; abstract in 1967 in Dissert. Abs., v. 28, no. 33, p. 951B.

141 Seeger, C. R., 1967, The Jeptha Knob structure, Kentucky, 2—rock deformation [abs.]: Meteorit. Soc. 30th Ann. Mtg., Moffett Field, Calif., 1967, Program.

KAALIJÄRV CRATERS, SAAREMA ISLAND, ESTONIA

See ref. 27.

KA-IMU-HOKU, LANAI, HAWAII

142 Barringer, Brandon, 1968, Lanai meteorite crater apparently myth: Meteoritics, v. 4, no. 1, p. 57–59.

A survey by air and on the ground revealed no depression at the place supposedly called Ka-imu-hoku, Hawaiian for "The Star Oven," on the island of Lanai. It had been reported as a "pit in the sand" or "the place where a meteor fell." Reasons are given for believing the name was based on native observation of a nineteenth-century fireball.

KENTLAND STRUCTURE, NEWTON COUNTY, IND.

143 Shrock, R. R., 1937, Stratigraphy and structure of the disturbed Ordovician rocks near Kentland, Indiana: Am. Midland Naturalist, v. 18, no. 4, p. 471–531.

See also ref. 28.

KILMICHAEL STRUCTURE, MONTGOMERY COUNTY, MISS.

See ref. 33.

KÖFELS SITE, ÖTZTAL, AUSTRIA

144 Heissel, Werner, 1965, Das "Bimssteinvorkommen" von Köfels im Otztal (Tirol) [The Köfels "pumice occurrence" in the Otztal (Tyrol)]: Neues Jahrb. Mineralogie Monatsh., 1965, nos. 9–11, p. 285–287.

Two new findings of "pumice" are reported and described.

LAC CHATELAIN, QUEBEC

(Lat 60°15′ N.; long 74°36′ W.)

See ref. 20.

LAC COUTURE, QUEBEC

145 Beals, C. S., Dence, M. R., and Cohen, A. J., 1967, Evidence for the impact origin of Lac Couture: Ottawa Dominion Observatory Pub., v. 31, no. 10, p. 409–426.

The belief that Lac Couture represents the eroded remnants of an ancient impact crater is based on abundances of rock breccia on the western islands and microscopic indications of crystals, particularly quartz, deformed and altered by shock in a manner found at other suspected impact sites.

146 Kitzes, Esther, 1964, Exploring craters in the earth: Nature and Sci., v. 1, no. 8, p. 10–12.

Ref.
147 Robertson, P. B., 1965, Petrography of the bedrock and breccia erratics in the region of Lac Couture, Quebec: University Park, Pennsylvania State Univ., M.S. thesis; included in ref. 53, v. 5, NASA–CR–74563.

See also refs. 1, 53.

LAKE BOSUMTWI, GHANA

147 El Goresy, Ahmed, 1966, Metallic spherules in Bosumtwi Crater glasses: Earth and Planetary Sci. Letters, v. 1, no. 1, p. 23–24.

148 Gentner, W., 1966, Auf der Such nach Kratergläsern, Tektiten und Meteoriten in Afrika [The search for crater glasses, tektites, and meteorites in Africa]: Naturwissenschaften, v. 53, no. 12, p. 285–289.

150 Kolbe, P., Pinson, W. H., Jr., Saul, J. M., and Miller, E., 1967, Rb-Sr study on country rocks of the Bosumtwi Crater, Ghana: Geochim. et Cosmochim. Acta, v. 31, no. 5, p. 869–875.

Metasedimentary country rocks from the immediate vicinity of the crater yield an age of 2,100±60 million years and support the theory that the Bosumtwi Crater glasses and Ivory Coast tektites formed by a complete meeting of metasediments that were present without addition of genetic material.

151 Jones, G. H. S., and Diehl, C. H. H., 1965, A scale model of the Bosomtwe Crater [abs.]: Astron. Jour., v. 70, no. 5, p. 324.

Comparison is made to an experimental crater produced by 500 tons of TNT at Suffield Experimental Station, Ralston, Alberta. An expanded report of this experiment was released in a 15-page unpublished report, 1965.

152 Lippolt, H. J., and Wasserburg, G. J., 1966, Rubidium-Strontium-Messungen an Gläsern vom Bosumtwi-Krater und an Elfenbeinküsten Tektiten [Rubidium-strontium measurements on glasses from the Bosumtwi Crater and on Ivory Coast tektites (with English abstract)]: Zeitschr. Naturforschung, v. 21a, no. 3, p. 226–231.

The Ivory Coast tektites and Bosumtwi glasses represent fusion products of similar materials.

153 Schnetzler, C. C., Philpotts, J. A., and Thomas, H. H., 1967, Rare-earth and barium abundances in Ivory Coast tektites and rocks from the Bosumtwi Crater area, Ghana: Geochim. et Cosmochim. Acta, v. 31, no. 10, p. 1987–1993.

154 Schnetzler, C. C., Philpotts, J. A., and Thomas, H. H., 1967, Trace element data on Ivory Coast tektites and rocks from the Bosumtwi Crater, Ghana [abs.]: Meteorites, v. 3, no. 3, p. 123.

155 Schnetzler, C. C., Pinson, W. H., and Hurley, P. M., 1966, Rubidium-strontium age of the Bosumtwi Crater area, Ghana, compared with the age of the Ivory Coast tektites: Science, v. 151, no. 3712, p. 817–819.

Evidence available at present suggests that the Ivory Coast tektites are most probably the fusion products of meteoritic impact at the Bosumtwi Crater site.

Ref.

156 Sky and Telescope, 1965, Bosomtwe—An African meteorite crater?: Sky and Telescope, v. 30, no. 1, p. 15.

The Jones-Diehl work (ref. 151) is reviewed.

157 Taylor, H. P., Jr., and Epstein, Samuel, 1966, Oxygen isotope studies of Ivory Coast tektites and impactite glass from the Bosumtwi Crater, Ghana: Science, v. 153, no. 3732, p. 173–175.

Oxygen isotope for six Ivory Coast tektites, two samples of Bosumtwi Crater glass, and two new moldavites are compatible with a terrestrial origin for the Ivory Coast tektites.

158 Wampler, J. M., Smith, D. H., and Cameron, A. E., 1966, Isotopic comparison of lead from Ivory Coast tektites and Bosumtwi Crater materials [abs.]: Am. Geophys. Union Trans., v. 47, no. 1, p. 145.

See also refs. 15, 17, 29, 33, 38, 39, 220.

LAKE HUMMELN, SWEDEN

159 Ashbrock, Joseph, 1967, Fossil meteorite crater: Sky and Telescope, v. 33, no. 2, p. 93.

160 Nature, 1967, Crater in the lake: Nature, v. 213, no. 5071, p. 7.

This reviews information presented in ref. 161.

161 Svensson, N. B., 1966, Lake Hummeln, a possible astrobleme in southern Sweden, I—The bottom topography: Sveriges Geol. Undersökning Årsb., ser. C. no. 608, 18 p.

This thesis discusses three theories for the origin of the Lake Hummeln depression: volcanism, tectonics, and meteoritic impact.

LAKE LAPPAJÄRVI, FINLAND

(Lat 63°10′N.; long 23°40′ E.)

162 McCall, G. J. H., 1968, Lake Lappajärvi, central Finland—a possible meteorite impact structure: Nature, v. 218, no. 5147, p. 1152.

163 Svensson, N. B., 1968, Lake Lappajärvi, central Finland—a possible meteorite impact structure: Nature, v. 217, no. 5127, p. 438.

Lamellae similar to those found in rocks of suspected meteorite craters are reported found in quartz in kärnäite boulders from an island in the lake.

164 Sky and Telescope, 1968, Another fossil meteor crater?: Sky and Telescope, v. 35, no. 4, p. 225.

This is a news note relative to ref. 163.

LAKE MIEN, SWEDEN

165 Svensson, N. B., and Wickman, F. E., 1965, Coesite from Lake Mien, southern Sweden: Nature, v. 205, no. 4977, p. 1202–1203.

The finding of coesite in the Lake Mein basin strongly supports the theory of its impact origin.

See also ref. 32.

Ref.

LAKE SILJAN, DALARNA, SWEDEN

166 Rutten, M. G., 1966, The Silijan ring of Paleozoic, central Sweden—a posthumous ring complex of a late Precambrian Dala Porphyries caldera; Geologie en Mijnbouw, v. 45, no. 5, p. 125–136.

It is postulated that the Siljan ring structure developed as a result of posthumous movements at the site of the ring-complex surrounding a caldera from which the Dala Porphyries had erupted earlier.

167 Stam, J. C., 1967, On the geology and tectonics of the Lake Silijan area, central Sweden: Geologie en Mijnbouw, v. 46, no. 11, p. 467–481.

The tectonic picture of Paleozoic formations is discussed. Evidence from surface geology and a number of drill cores indicate a more complicated structure than previously believed.

LONAR LAKE, INDIA

168 LaFond, E. C., and Dietz, R. S., 1964, The Lonar Crater (India)—Meteorite crater?: Indian Geophys. Union Jour., v. 1, no. 2, p. 91–97.

A recent field reconnaissance has tended to support the view that the Lonar Crater is probably a Quaternary meteorite crater.

169 Nandy, N. C., and Deo, V. B., 1961, Origin of the Lonar Lake and its salinity: TISCO, v 8, no. 3, p. 144–155.

170 Venkatesh, V., 1965, Geochemical evidence for the origin of the Lonar crater, Maharashtra, India: Geol. Soc. American Bull., v. 76, no. 11, p. 1315–1316; discussion by H. E. Hawkes, 1967, v. 78, no. 9, p. 1199–1200; reply by author, p. 1201–1202.

The observation that nickel and cobalt content of soils, plants, lake sediment, and brines collected within the crater shows no perceptible difference from that of similar material collected at a distance of 10 kilometers from the crater suggests the lack of meteoritic material in the crater. Hawkes answers that experimental sampling at Meteor Crater does not support the suggestion that nickel content of soils and plants can be used as an evidence of meteoritic origin.

NICHOLSON LAKE, CANADA

(Lat 47°39′ N.; long 70° 11′ W.)

171 Robertson, P. B., 1967, The Malbaie structure, Quebec—an ancient meteorrite impact site [abs.]: Meteorite. Soc., 30th Ann. Mtg., Moffett Field Calif., 1967, Program.

MANICOUAGAN-MUSHALGAN LAKES AREA, QUEBEC

172 Currie, K. L., and Murtaugh, J. D., 1968, A preliminary map of the Manicouagan structure: Canada Geol. Survey Paper 67–70.

173 Fleischer, R. L., and Price, P. B., 1968, Fission track dating of glass from the Manicouagan crater [abs.]: Am. Geophys. Union Trans., v. 49, no. 1, p. 272–273.

Ref.

174 Larochelle, André, and Currie, K. L., 1967, Paleomagnetic study of igneous rocks from the Manicouagan structure, Quebec: Jour. Geophys. Research, v. 72, no. 16, p. 4163–4169.

Statistical analysis of the data shows that formation of the Manicouagan group has taken 10,000 years or less.

175 Robertson, W. A., 1967, Manicouagan, Quebec, paleomagnetic results: Canadian Jour. Earth Sci., v. 4, no. 4, p. 641–649.

Comparison with other North American paleomagnetic poles points to a possible Triassic age for dacitic material from Manicouagan.

See also refs. 11, 12, 20, 21, 23, 57.

MECATINA CRATER, QUEBEC

See ref. 53.

MEREWETHER CRATER, LABRADOR

See ref. 53.

MIDDLESBORO BASIN, BELL COUNTY, KY.

176 Dietz, R. S., 1966, Shatter cones at the Middlesboro structure, Kentucky: Meteoritics, v. 3, no. 1, p. 27–29.

Shatter cones have been found in two boulders in the central uplift of the structure.

MONTURAQUI CRATER, CHILE

(Lat 23°55.6′ S.; long 68°16.7′ W.)

177 Bunch, T. E., and Cassidy, W. A., 1967, Petrographic and electron microprobe study of the Monturaqui impactite [abs.]: Meteorit. Soc., 30th Ann. Mtg., Moffett Field, Calif., 1967, Program.

178 Sanchez, Joaquin, and Cassidy, W. A., 1966, A previously undescribed meteorite crater in Chile: Jour. Geophys. Research, v. 71, no. 20, p. 4891–4895; abstract in Am. Geophys. Union Trans., v. 47, no. 1, p. 144.

This newly discovered crater, 455 meters average diameter and 31 meters average depth, may have been formed by the same meteroid that caused the Campo del Cielo Craters. Iron shale and impactite material are evidences of its impact origin.

179 Sanchez, Joaquin, and Cassidy, W. A., 1968, A previously undescribed meteorite crater in Chile [abs.]: Conference on shock metamorphism of natural materials, April 14–16, 1966 Goddard Space Flight Center, Greenbelt, Md., Program, p. 34.

NASTAPOKA ISLANDS ARC, HUDSON BAY, CANADA

180 Schwarz, H. P., 1965, The origin of diamonds in drift of the north central United States: Jour. Geology, v. 73, no. 4, p. 657–663.

Diamonds found in Wisconsin drift in Ohio, Indiana, Michigan, and Wisconsin were perhaps carried south from an ancient impact crater presently outlined by the Nastapoka Islands arc.

See also ref. 45.

Ref.

NEW QUEBEC CRATER, UNGAVA, QUEBEC

181 Currie, K. L., 1965, The geology of the New Quebec Crater: Canadian Jour. Earth Sci., v. 2, no. 3, p. 141–160.

The volcano-tectonic hypothesis for the origin of the New Quebec Crater is considered somewhat more attractive than the impact one, since it explains all the structural and petrographic features of the crater and since there is no evidence of shock criteria. However, the type of volcanics observed has not been seen in classical volcanic areas; the real evidence lies beneath 800 feet of water.

182 Currie, K. L., 1966, Geology of the New Quebec crater [French abs.]: Canada Geol. Survey Bull. 150, 36 p.

Evidence is quantitatively consistent with an origin by collapse of a fluid-supported dome.

See also refs. 1, 6, 20, 23, 53.

NICHOLSON LAKE, NORTHWEST TERRITORIES, CANADA

(Lat 62°40′ N.; long 102°41′ W.)

See refs. 6, 43.

ODESSA CRATERS, ECTOR COUNTY, TEX.

183 Barringer, Brandon, 1967, Historical notes on the Odessa meteorite crater: Meteoritics, v. 3, no. 4, p. 161–168.

D. M. Barringer, Jr., identified the crater in 1926. This article reviews his work, with notes on subsequent exploration.

184 Roach, C. H., Lassiter, S. P., and Sterrett, T. S., 1965, Mercury distribution at the Odessa meteorite craters, Texas, *in* Astrogeologic studies annual progress report, July 1, 1964, to July 1, 1965, pt. B: U.S. Geol. Survey open-file rept., p. 151–163.

This report compares mercury content of subsurface rocks at the craters with that of stratigraphically equivalent surface rocks about 1 mile from the craters.

PATOMSKII CRATER, IRKUTSK OBLAST, U.S.S.R.

185 Krotova, Z. A., and Kandyba, Yu. L., 1966, Issledovaniye Patomskogo kratera [Investigation of the Patomsk crater]: Meteoritika, no. 27, p. 134–138.

A 1963 expedition made magnetic, induction, and metallometric surveys at the Patomsk site without finding evidence of a large magnetic body, although magnetite particles in the region were recovered.

PILOT LAKE, NORTHWEST TERRITORIES, CANADA

See refs. 1, 43.

PRETORIA SALT PAN, SOUTH AFRICA

See refs. 1, 53.

PUCHEZH-KATUNKI CRATER, U.S.S.R.

(Lat 56°30′ N.; long 43° E.)

186 Firsov, L. V., 1965, O meteoritnom proiskhozhenii Puchezh-Katunskogo kratera [On the meteoritic origin of the Puchezh-Katunki crater]: Geotektonika, 1965, no. 2, p. 106–118.

Ref.

RICHÂT CRATER, MAURITANIA

187 Trompette, Roland, and Joulia, François, 1966, Sur l'origine des analcimolites glomérulaires des Richât République Islamique de Mauritanié [Origin of clustered analcime rocks from Richât (Mauritania)]: Acad. Sci. [Paris] Comptes rendus, sér. D, v. 262 no. 12, p. 1327–1330.

An origin either as spring deposits or as playa lake sediments is considered possible.

See also ref. 237.

RIESKESSEL, BAVARIA, GERMANY

188 Angenheister, Gustav, 1965, Bemerkungen zu den Vermessungen des erdmagnetischen Feldes im Ries und seiner Umgebung (1902–65) [Remarks on the surveys of the geomagnetic field in the Ries and its vicinity (1902–65)]: Neues Jahrb. Mineralogie Monatsh., 1965, nos. 9–11, p. 260–267 [with English summary].

Results of eight total-intensity magnetic profiles across the Ries and its vicinity are compared with those of earlier ground magnetic surveys.

189 Angenheister, Gustav, and Pohl, Jean, 1967, Beiträge der Geophysik zur Erforschung des Rieses von Nördlingen [The contribution of geophysics to the investigation of the Nördlingen Ries]: Naturwissenschaften, v. 54, no. 9, p. 209–216.

190 Barthel, K. W., 1964, Das Ries und sein Werden—Eine geologische Skizze [The Ries and its origin—a geological sketch]: Oettingen, Fränkisch-Schwäbischer Heimatverlag, 55 p.

191 El Goresy, Ahmed, 1964, Die Erzmineralien in den Ries-und Bosumtwi-Krater-Gläsern und ihre genetische Deutung [The ore minerals in the Ries and Bosumtwi crater glasses and their genetic significance]: Geochim. et Cosmochim. Acta, v. 28, no. 12, p. 1881–1891. [with English abstract].

Results of ore-microscopy investigations on suevites are discussed as suggestive of a meteorite impact origin.

192 El Goresy, Ahmed, and Donnay, G., 1963, A new allotropic form of carbon from the Ries crater: Science, v. 161, no. 3839, p. 363–364.

193 Engelhardt, Wolf von, 1965, Mineralogische und petrographische Untersuchungen an Gesteinen des Ries [Mineralogical and petrographic investigations on rocks of the Ries]: Neues Jahrb. Mineralogie Monatsh., 1965, nos. 9–11, p. 354–357.

Investigations on suevite from the Ries are reviewed.

194 Engelhardt, Wolf von, 1967, Chemical composition of Ries glass bombs: Geochim. et Cosmochim. Acta, v. 31, no. 10, p. 1677–1689.

Thirty-two chemical analyses of glass bombs from various suevite localities in and near the Ries are presented; two main glass types can be distinguished.

Ref.

195 Engelhardt, Wolf von, 1967, Neue Beobachtungen im Nördlinger Ries [New investigations in the Nördlingen Ries]: Geol. Rundschau, v. 57, no. 1, p. 165–188 [with English summary].

Negative anomalies are confirmed; deep drilling confirms the supposition that the Tertiary lake sediments are underlain by suevite which is clearly distinguishable from volcanic tuff.

196 Engelhardt, Wolf von, and Stöffler, Dieter, 1968, Stages of shock metamorphism in the crystalline rocks of the Ries Basin (Germany), *in* French, Bevan, and Short, N. M., eds., Shock metamorphism of natural materials: Baltimore, Md., Mono Book Corp., p. 159–168.

197 Engelhardt, Wolf von, Arndt, J., Stöffler, Dieter, Müller, W. F., Jeziorkowski, H., and Gubser, R. A., 1967, Diaplektische Gläser in den Breccien des Ries von Nördlingen als Anzeichen für Stosswellenmetamorphose [Diaplectic glasses in the breccia of the Nördlingen Ries as evidence of shock metamorphism]: Contr. Mineralogy and Petrology, v. 15, no. 1, p. 93–102 [with English abstract].

Two kinds of shock-produced glasses are found in the Ries basin breccias: normal glasses and diaplectic glasses.

198 Engelhardt, Wolf von, and Hörz, Friedrich, 1965, Riesgläser und Moldavite [Ries glasses and moldavites]: Geochim. et Cosmochim. Acta, v. 29, no. 6, p. 609–620 [with English abstract].

The authors feel that the composition of moldavites cannot be related to the crystalline material of the Ries; a common origin is therefore improbable.

199 Fischer, Georg, 1965, Einige Betrachtungen zur Genesis des Rieses [Some considerations on the genesis of the Ries]: Neues Jahrb. Mineralogie Monatsh., 1965, nos. 9–11, p. 310–315.

The concept that meteorite impact may have triggered volcanic activity would provide a basis for relating the Steinheim Basin and Urach volcanic region to the Ries.

200 Förstner, Ulrich, 1967, Petrographische Untersuchungen des Suevit aus den Bohrungen Deiningen und Wörnitzostheim im Ries von Nördlingen [Petrographic investigation of suevite in drill holes of Deiningen and Wörnitzostheim in the Nördlingen Ries]: Contr. Mineralogy and Petrology, v. 15, no. 4, p. 281–308 [with English abstract].

The breccia contains glass and shattered crystalline fragments in different stages of shock metamorphism.

201 Hörz, Friedrich, 1965, Beobachtungen an den Riesgläsern [Observations on the Ries glasses]: Neues Jahrb. Mineralogie Monatsh., 1965, nos. 9–11, p. 324–327 [with English summary].

Observations made relate to high temperature and pressure characteristics of the Ries glass.

202 Hörz, Friedrich, 1965, Geologische Beobachtungen zur Entstehung der Suevite [Geological observations on the origin of the suevites]: Neues

Ref.

Jahrb. Mineralogie Monatsh., 1965, nos. 9–11, p. 322–323 [with English summary].

Field evidence suggests that the suevite occurrences of the Ries do not represent individual pipes but are remnants of continuous cover formed as a product of the last Ries explosion.

203 Hörz, Friedrich, 1965, Untersuchungen an Riesgläsern [Observations on the Ries glasses]: Beitr. Mineralogie u. Petrographie, v. 11, no. 7, p. 621–661.

Shapes of the Ries glasses, the finding that suevite is rootless, and real high-pressure glasses found on remelting Ries glass lead the author to conclude that the Ries is of impact origin.

204 Hüttner, R., and Wagner, G. H., 1965, Uber Lagerung und Herkunft einiger Suevitvorkommen [On the position and origin of some suevite occurrences]: Neues Jahrb. Mineralogie Monatsh., 1965, nos. 9–11, p. 316–322 [with English summary].

The suevites of the Ries area appear to be rootless.

205 Johnson, G. C., and Vand, Vladimir, 1967, Application of a Fourier data smoothing technique to the meteoritic crater Ries Kessel: Jour. Geophys. Research. 72, no. 6, p. 1741–1750.

206 Jung, Karl, 1965, Gravimetermessungen in der Umgebung des Rieses [Gravimetric measurements in the vicinity of the Ries]: Neues Jahrb. Mineralogie Monatsh., 1965, nos. 9–11, p. 277–279 [with English summary].

207 Jung, Karl, Menzel, Heinz, and Rosenbach, Otto, 1965, Gravimeter-messungen im Nördlinger Ries [Gravimeter measurements in the Nördlingen Ries]: Zeitschr. Geophysik, v. 31, no. 1, p. 7–26 [with English summary].

208 Jung, Karl, and Schaaf, H., 1967, Gravimetermessungen im Nördlinger Ries und seiner Umgebung, Abschätzung der gesamten Defizitmasse [Gravimeter surveys in the Nördlingen Ries and its vicinity—Estimation of the total mass deficit]: Zeitschr. Geophysik, v. 33, no. 5, p. 319–345.

Results of a gravity survey in the area surrounding the Ries are shown in a map of isograms of the Bouguer gravity anomalies and a table containing all gravity and topographic data of the stations.

209 Mosebach, Rudolf, 1964, Das Nördlinger Ries, vulkanischer Explosionskrater oder Einschlagstelle eines Grossmeteoriten? [The Nördlingen Ries, a volcanic explosion crater or place of impact of a large meteorite?]: Oberhessischen Gesell. Natur-u. Heilkunde Giessen Ber., Naturw. Abt., v. 33, nos. 1–3, p. 165–204.

210 Pohl, Jean, 1965 Die Magnetisierung der Suevite des Rieses [The megnetization of the suevites of the Ries]: Neues Jahrb. Mineralogie Monatsh., 1965, nos. 9–11, p. 268–276 [with English summary].

The intensity and direction of magnetization suggest that suevite may be the cause of the negative anomaly over the Ries.

211 Preuss, Ekkehard, 1965, Ein Tektit-artiger Glaskörper aus dem Suevit von Goldburghausen im Ries [A tektitelike glass body from the suevite at

Ref.

Goldburghausen in the Ries]: Neues Jahrb. Mineralogie Monatsh., 1965, nos. 9–11, p. 327–331 [with English summary].

It is suggested that the moldavites were formed from layers of the Mesozoic complex at the same time as the Ries crater.

212 Preuss, Ekkehard, 1965, Zum Ries-Kolloquium am 25. und 26. Juni 1965 in Tübingen [On the Ries symposium on June 25 and 26, 1965, in Tübingen]: Neues Jahrb. Mineralogie Monatsh., 1965, nos. 9–11, p. 257–260.

213 Remo, John, 1967, A physical model for the terrestrial origin of tektites [abs.]: Meteoritics, v. 3, no. 3, p. p. 122.

A theoretical study of tektite formation is made, using the Ries Crater as a model.

214 Stöffler, Dieter, 1965, Anzeichen besonderer mechanischer Beanspruchung an Mineralien der Kristallineinschlüsse des Suevits (Stosswellenmetamorphose) [Marks of special mechanical stress on minerals of the crystalline inclusions in the suevite (shock-wave metamorphism)]: Neues Jahrb. Mineralogie Monatsh., 1965, nos. 9–11, p. 350–354.

Shock-wave-induced deformations and transformations are found to decrease in degree outward from the center of the Ries Basin.

215 Stöffler, Dieter, 1966, Zones of impact metamorphism in the crystalline rocks of the Nördlingen Ries crater: Beitr. Mineralogie u. Petrographie, v. 12, no. 1, p. 15–24.

Fragments of crystalline basement rocks in suevite display a continuous gradation of metamorphism. A classification of varying impact facies in crystalline rocks is proposed.

216 Stöffler, Dieter, 1967, Deformation und Umwandlung von Plagioklas durch Stosswellen in den Gesteinen des Nördlinger Ries [Deformation and transformation of plagioclase by shock in rocks of the Nördlingen Ries]: Contr. Mineralogy and Petrology, v. 16, no. 1, p. 51–83 [with English abstract].

Plagioclase from fragments of crystalline basement rocks in breccias of the Ries area displays characteristic plastic deformation and phase transition phenomena due to shock metamorphism at different pressures in the range of 100–1,000 kilobars.

217 Treibs, Walter, 1965, Beitrag zur Kenntnis der Geologie des Rieses und ostlichen Vorrieses nach Beobachtungen in Rohrgraben der Rein-Donau-Ölleitung [Contribution to the knowledge of the geology of the Ries and the eastern Vorries from an observation of pipes of Rhein-Donau-Ölleitung]: Geol. Bavarica, no. 55, p. 310–316.

218 Triebs, Walter, 1965, Geologische Beobachtungen beim Bau der Rhein-Donau-Ölleitung im bayerischen Teil des Rieses und im östlichen Vorries [Geologic observations during construction of the Rhine-Danube oil pipeline in the Bavarian part of the Ries and east of the Ries]: Neues Jahrb. Mineralogie Monatsh., 1965, nos. 9–11, p. 308–309.

Excavations revealed the extent of the "bunte breccia" and some new occurrences of suevite.

Ref.
219 Wagner, G. H., 1964, Kleintektonische Untersuchungen im Gebiet des Nördlinger Rieses [Microtectonic investigation in the region of the Nördlingen Ries]: Geol. Jahrb., v. 81, no. 6, p. 519–600 [with English abstract].

220 Zähringer, Joseph, and Gentner, Wolfgang, 1966, Stravitel'noye opredeleniye kali-afrgonovogo vozrasta tektitov, stekol Nördlinger Ris (FRG), Bosumtvi (Gana) i drugikh prirodnykh stekol [Comparative determination of the potassium-argon age of tektites, glasses of the Nördlingen Ries (West Germany), Bosumtwi (Ghana), and other natural glasses]: Meteoritika, no. 27, p. 151–152.

221 Ziehr, Heinz, 1965, Uranhaltige Süsswasserkalke am Steinberg im Ries [Uranium-bearing freshwater limestones at Steinberg in the Ries]: Neues Jahrb. Mineralogie Monatsh., 1965, nos. 9–11, p. 358–367.

See also refs. 9, 11, 15, 17, 18, 29, 32, 33, 38, 39, 57, 99, 103.

ROTER KAMM, SOUTH AFRICA

(Lat 27°46′ S.; long 16°18′ E.)

222 Dietz R. S., 1965, Roter Kamm, Southwest Africa—probable meteorite crater: Meteoritics, v. 2, no. 4, p. 311–314.

This is the first reporting of a highly probable impact crater, 1.5 miles across and depressed 400 feet below the rim and 100 feet below the surrounding plain.

223 Dietz, R. S., 1966, Addendum to paper on Roter Kamm: Meteoritics, v. 3, no. 1, pp. 33–34.

The Roter Kamm bolide is computed to have been about 92 meters in diameter; the apparent depth of the crater, 4,700 feet; the depth of crater fill, 4,300 feet.

SERPENT MOUND STRUCTURE, ADAMS COUNTY, OHIO

224 Bull, C. B., Corbato, C. E., and Zahn, J. C., 1967, Gravity survey of the Serpent Mound area, southern Ohio: Ohio Jour. Sci., v. 67, no. 6, p. 359–371.

A closely spaced network of gravity stations extending beyond the limits of the surface expression of the ring structure shows no gravity anomaly pattern that can be related to the surface features.

SIERRA MADERA STRUCTURE, PECOS COUNTY, TEX.

225 Howard, K. A., and Offield, T. W., 1968, Shatter cones in Sierra Madera, Texas: Science, v. 162, no. 3850, p. 261–265.

226 Kelly, A. O., 1966, A water-impact hypothesis for the Sierra Madera structure in Texas: Meteoritics, v. 3, no. 2, p. 79–82.

227 Lowman, P. D., Jr., 1965, Magnetic reconnaissance of Sierra Madera, Texas, and nearby igneous intrusions, *in* Geological problems in lunar research: New York Acad. Sci. Annals, v. 123, art. 2, p. 1182–1197.

This paper presents the results of a magnetic reconnaissance of Sierra Madera and three igneous intrusions, made in 1961; it is concluded that the balance of evidence presently favors the theory that the Sierra Madera

Ref.

structure is the result of displacement and brecciation by a syenite intrusion under the southeast corner.

228 Wilshire, H. G., and Howard, K. A., 1968, Structural patterns in central uplifts and cryptoexplosion structures as typified by Sierra Madera: Science, v. 162, no. 3850, p. 258–261.

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

See ref. 47.

SOCOTRA CRATER, SOCOTRA

229 Milton, D. J., 1965, Alleged meteorite crater on Soqotra: British Astron. Assoc. Jour., v. 75, no. 4, p. 283.

This note reports correspondence with geologists in the Aden area, which suggests that the Socotra feature be eliminated from lists of possible impact structures.

STEEN RIVER STRUCTURE, ALBERTA

(Lat 51° N.; long 117° W.)

See ref. 61.

STEINHEIM BASIN, GERMANY

230 Engelhardt, Wolf von, Bertsch, W., Stöffler, Dieter, Groschopf, P., and Reiff, W., 1967, Anzeichen für den meteoritischen Ursprung des Beckens von Steinheim [Evidence for the meteoritic origin of the Steinheim basin]: Naturwissenschaften, v. 54, no. 8, p. 198–199.

231 Groschopf, P., and Reiff, W., 1966, Ergebnisse neuerer Untersuchungen im Steinheimer Becken [Result of a new investigation in the Steinheim Basin]: Ver. Vaterländ. Naturkunde Württemberg Jahreshefte, v. 121, p. 155–168.

232 Jensch, A., 1965, Geophysikalische Messungen im Steinheimer Becken [Geophysical measurement in the Steinheim basin]: Neues Jahrb. Mineralogie Monatsh., 1965, nos. 9–11, p. 279–284 [with English summary.]

Three phases of formation can perhaps be defined.

See also ref. 199.

SUDBURY BASIN, ONTARIO

233 Bray, J. G., and others, 1966, Shatter cones at Sudbury: Jour. Geology, v. 74, no. 2, p. 243–245.

Field distribution and orientation of shatter cones are not incompatible with the idea of Sudbury as an astrobleme, but the author withholds judgment on impact origin pending further data.

234 French, B. M., 1967, Sudbury structure, Ontario—some petrographic evidence for origin by meteorite impact: Science, v. 156, no. 3778, p. 1094–1098; abstract in Meteoritics, v. 3, no. 3, p. 110.

Unusual deformation structures, similar to those observed in rocks from known and suspected meteorite impact craters, are observed in inclusions of basement rock in the Onaping Formation at Sudbury. It is suggested that the Onaping Formation consists of shocked and melted material deposited immediately after a meteorite impact which formed the Sudbury basin.

Ref.
235 Sudbury Field Trip Committee, 1966, Sudbury nickel irruptive tour, *in* Inst. Lake Superior Geology, 12th ann., 1966: Sault Ste. Marie, Mich., Michigan Technol. Univ., 11 p.

A bibliography of Sudbury basin geology is included.

See also refs. 28, 57.

TENOUMER CRATER, MAURITANIA

236 Monod, Théodore, and Pomerol, Charles, 1966, Le cratère de Tenoumer (Mauritanie) et ses laves [The Tenoumer crater (Mauritania) and its lavas]: Soc. Géol. France Bull., ser. 7, v. 8, no. 2, p. 165–172.

The authors consider this structure to be a caldera of the ring-dike type.

TIBESTI CRATER, CHAD

(Lat 21°30′ N.; long 17°30′ E.)

237 Lowman, P. D., Jr., McDivitt, J. A., and White, E. H., 2d, 1967, Terrain photography on the Gemini-IV mission—preliminary report: U.S. Natl. Aeronautics and Space Adm. Tech. Note D–3982, 15 p.

Figure 6, page 9, shows a previously unknown circular structure in the Tibesti Mountains, 110 kilometers south and 42° west of the volcano Emi Koussi.

238 Mumford, G. S., 1967, New giant crater in Africa?: Sky and Telescope, v. 34, no. 1, p. 12.

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VERSAILLES STRUCTURE, WOODFORD COUNTY, KY.

257 Black, D. F. B., 1965, Cryptoexplosion structure near Versailles, Kentucky, *in* Geol. Soc. Kentucky, Field trip 1965: Lexington, Kentucky Geol. Survey, p. 44–51 [originally published 1964].

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258 Manton, W. I., 1965, The orientation and origin of shatter cones in the Vredefort Ring, *in* Geological problems in lunar research: New York Acad. Sci. Annals, v. 123, art. 2, p. 1017–1049.

The author discusses here the problem of shatter cone location in the Vredefort Ring and objection to a shock wave origin.

See also refs. 1, 9, 13, 28, 45.

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259 Short, N.M., 1966, Shock-lithification of unconsolidated rock materials: Science, v. 154, no. 3747, p. 382–384.

Sandstonelike lumps found at Wabar are similar to shock-lithified sands produced by explosion shock.

See also refs. 8, 15–17, 29, 58, 59.

WELLS CREEK STRUCTURE, STEWART COUNTY, TENN.

260 Starns, R. G., Wilson, C. W., Jr., Tiedemann, H. A., Wilcox, J. T., and Marsh, P. S., 1968, The Wells Creek structure, Tennessee, *in* French, Bevan, and Short, N. M., eds., Shock metamorphism of natural materials: Baltimore, Md., Mono Book Corp., p. 323–338.

The most likely origin of the Wells Creek structure is believed to be meteor impact because of shatter-cone orientation and distribution.

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WEST HAWK LAKE, MANITOBA

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266 Halliday, Ian, and Griffin, A. A., 1967, Summary of drilling at the West Hawk Lake crater: Royal Astron. Soc. Canada, v. 61, no. 1, p. 1–8; reprinted in Ottawa Dominion Observatory Contr., v. 4, no. 25, 8 p.

Results from a second diamond drilling are described; the present lake was probably derived by severe erosion of a crater originally 9,000 feet in diameter.

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WOLF CREEK CRATER, WESTERN AUSTRALIA

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269 McCall, G. J. H., 1965, Possible meteorite craters—Wolf Creek, Australia and analogs, *in* Geological problems in lunar research: New York Acad. Sci. Annals, v. 123, art. 2, p. 970–998.

Shale balls containing only minute specks of native metal and no association with fresh iron fragments are found in this enigmatic crater. Diatremes and at least one diapiric structure are located nearby. Conflicting evidence seems to favor a crytovolcanic origin for the crater.

See also refs. 57, 88, 95.

AUTHOR INDEX

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