Bibliography of Terrestrial Impact Structures

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U.S. Geological Survey
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Introduction

This bibliography encompasses in one report the individual bibliographies of 105 (12 proven and 93 probable) terrestrial impact structures. The bibliography of each impact structure was compiled for inclusion in an "Atlas of terrestrial impact structures" to be published at a later date. The bibliographies are being released in advance of the Atlas in order to make them immediately available to specialists interested in impact and cratering processes.

An attempt was made in this compilation to update the comprehensive bibliography of terrestrial impact structures and its supplement published earlier by the U.S. Geological Survey (Freeberg, 1966, 1969). In the last 15 years, the volume and range of the literature concerning impact structures has increased dramatically, making existing bibliographies incomplete.

Historical Guide to Literature on Terrestrial Impact Structures

Since the late 1950's, the subject of meteorite impact on Earth has attracted hundreds of research workers from many disciplines. Over the years, the emphasis on its different scientific aspects has followed the development of planetology. Most of the major developments in meteorite-impact research were punctuated by a symposium that both highlighted and keynoted the main results of on-going research, and emphasized their significance with respect to developments in allied disciplines. The proceedings of these symposia are referenced below, because each of them is an index to much of the specialized literature that was being published at the time they were held:


Of equal importance to these three symposia in setting the direction of meteorite-impact research has been work on multi-ring basins, asteroids, and comets. The research on multi-ring basins is summarized in:


The leaders in research on asteroids and comets that bears on the origin of bodies impacting on the Earth have been Öpik, Shoemaker, Urey, and Wetherill.

In the 1960's, interest in meteorite impact on Earth centered on 1) the very large energies released and associated effects produced by impact and man-made nuclear explosions (Bolt, 1976); and on 2) the morphological analogy of lunar craters to fresh terrestrial impact structures. Quite appropriately, the Conference on shock Metamorphism of Natural Materials in April 1966 linked the results of shock-wave research that had been derived from investigations.
of meteorite-impact structures, nuclear explosions, and laboratory experiments. As the Inner and Outer parts of the Solar System were explored in the 1970's, largely as a result of the Planetology Program of the National Aeronautics and Space Administration (NASA), interest in cratering mechanics increased—it was realized that cratering by impact had played a major role in the evolution of all terrestrial planets and the satellites of the outer planets. The Symposium on Planetary Cratering Mechanics in September 1976 provided a forum for the most active researchers in impact and explosion cratering to exchange ideas and state-of-the-art techniques, and to discuss areas of common interest. A number of papers in the proceedings of this symposium deal with cratering phenomenology and terrestrial cratering.

Lately, research in terrestrial impact structures has received a new orientation and a tremendous boost, following the formulation by Alvarez and others (1980) of an hypothesis that suggests impact as the cause of the worldwide Cretaceous-Tertiary biological extinctions. This hypothesis, inspired by the discovery of iridium anomalies at the Cretaceous-Tertiary boundary, re-introduced catastrophism as a catalyst and a driving force into contemporary geologic thought. It was the backdrop against which the Conference on Large-Body Impacts was convened in October 1981.

The origin of bodies that formed terrestrial impact structures has been a matter of conjecture and controversy for a very long time. These bodies are now known to have been meteorites, unrelated to planetesimals, like those that collided with other bodies of the Inner Solar System very early in its history to create very large basins. The origin of impacting populations in very early Archean time, the origin and behavior of Earth-crossing asteroids and comets, and impact-cratering rates are three fields of research critical to the understanding of space and time distributions of terrestrial impact
structures. These fields have rapidly expanded during the past decade, yet they have not been the themes of specialized symposia. For that reason, bibliographies—necessarily incomplete—dealing with these topics are also included in this compilation.

The economic importance of some terrestrial impact structures was not recognized until long after they had been developed for mining of ore (Sudbury Basin, Vredefort Structure, Carswell Lake Structure), or petroleum extraction (Red Wing Creek, Steen River Structure). Dietz (1961, 1964) and French (written communication, 1969) drew attention to the economic potential of several of these structures, but so far their economic interest as a group has paled in comparison to their serving as mute testimony to one of the major planetary geologic processes.

Purpose and Scope

This compilation is based on the list of proven and probable impact structures most recently updated by Grieve (1982). It includes the 11 proven craters listed by Shoemaker and Eggleton (1961) in their crater category 1 (craters or clusters of craters with associated meteorites). To it, Grieve added the Morasko Craters in Poland, which he upgraded from category 6 of Shoemaker and Eggleton (1961). It does not include, however, Sobolev, Asian USSR listed in this group by Grieve and Robertson (1979), Macaytis and others (1980) and Shoemaker (1983), nor Monturaqui Crater (Shoemaker, 1983).

The craters listed in categories 2, 3 and 4 of Shoemaker and Eggleton (1961) are now considered probable impact structures, with the following exceptions: Richat Crater, Mauritania; Pretoria Salt Pan, South Africa; Glasford Structure, Illinois; Howell Structure, Tennessee; Jephta Knob Structure, Kentucky; Kilmichael Structure, Mississippi; and the Versailles Structure, Kentucky. Many of the craters in categories 5 and 6 of Shoemaker
and Eggleton (1961) have been upgraded by Grieve (1979, 1982) to "probable impact structure" status; they are as follows: Upheaval Dome, Utah; Amguid Crater, Algeria; Carswell Lake Structure, Saskatchewan; Deep Bay, Saskatchewan; Glover Bluff Structure, Wisconsin; Lac Couture, Quebec; Lake Dellen, Sweden; Lake El'gyykyn, U.S.S.R.; Lake Mien, Sweden; Lake Siljan, Sweden; Patomskii Crater, U.S.S.R.; Pilot Lake, Northwest Territories, Canada; Sudbury Basin, Ontario; Tenoumer Crater, Mauritania; and West Hawk Lake, Manitoba. Upheaval Dome, Utah, and the Glover Bluff Structure, Wisconsin, though not listed by Grieve (1982), are included in this compilation as a result of work since 1982. Many additional impact structures not listed by Shoemaker and Eggleton (1961) are considered by Grieve (1982) to be probable impact craters, and are included in this compilation.

No attempt to evaluate the entries has been made, as had been by Freeberg in her 1966 bibliography and 1969 supplement, because of the vast increase in number of entries. Most of them were read, however, prior to the preparation of the Atlas referred to above. Since 1975 there has been an increasing trend toward in-depth analysis of many terrestrial impact structures, and a greater range of specialized studies in geomorphology, petrography, age dating, crater mechanics, paleomagnetism, geophysics, geochemistry and cosmochemistry, regional field geology, and archeology. Such specialization has coincided in part with investigations sponsored under the NASA Planetology Program. The cutoff date on most entries is mid-1983, but a few 1984 entries are included.

Impact structures are listed alphabetically by continent. No proven nor probable impact structures are listed for Greenland and the Antarctic, and none is known on the ocean floor (Eckhoff and Vogt, 1981). However, the hypothesis that very large impact basins in early Archean time were the
original ocean basins has many supporters. Chenoweth (1958), Dietz (1959), Harrison (1960), and Gromov (1961, 1962) advocated the hypothesis before Mesozoic and Cenozoic ocean-floor spreading became known as the generating mechanism of present ocean-floor crust. Thereafter, its supporters included Frey (1980) and Grieve (1980). Each continent is listed below in decreasing order, according to the amount of research in impact structures that it has generated:

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<tr>
<td>Wisconsin 1</td>
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<tr>
<td>Canada: 23</td>
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<tr>
<td>Alberta 1 (Steen River Structure: buried)</td>
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</tr>
<tr>
<td>Manitoba 2</td>
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<tr>
<td>Newfoundland (Labrador) 1</td>
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6
<table>
<thead>
<tr>
<th>Region</th>
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<td>Ontario</td>
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<td>Quebec</td>
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<tr>
<td>Saskatchewan</td>
<td>3</td>
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<tr>
<td>South America: Total 5</td>
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<td>Argentina</td>
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<tr>
<td>Brazil</td>
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<tr>
<td>Chile</td>
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<tr>
<td>Australia: Total 11</td>
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<td>Western Australia</td>
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<tr>
<td>Northern Territory</td>
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<td>Europe (exclusive of USSR): Total 10</td>
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<td>Finland</td>
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<td>Sweden</td>
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<td>European USSR: Total 18</td>
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<tr>
<td>Byelorussian SSR</td>
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<tr>
<td>(Logoisk: buried)</td>
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<td>Estonian SSR</td>
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<tr>
<td>Karelian SSR</td>
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<tr>
<td>(Kjardla: buried)</td>
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<td>Latvian SSR</td>
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<tr>
<td>(Misarai and Vepria: both buried)</td>
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<tr>
<td>Lithuanian SSR</td>
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<tr>
<td>(of which Kaluga, Kamensk-Gusev, Kursk, and Puchezh-Katunki are buried)</td>
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<tr>
<td>Russian SFSR</td>
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<tr>
<td>Tatar SSR</td>
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</table>
Ukrainian SSR

6 (of which Boltysk, Il'inets, Obolon, Rotmistrovka, and Zelenyy-Gay are buried)

Asia: Total 12

India 1
-Mongolia 1
Saudi Arabia 1

Asian USSR: Total 9

Kazakh SSR 2
Primoriye Terr. 1
Russian SFSR 4 (of which Kara is partly buried)
Yakotskh SSR 1

Africa: Total 10

Algeria 4
Ghana 1
Libya 2
Mauritania 2
South Africa 1

Most impact structures in the European USSR (13) are buried under sedimentary rocks, and are detectable only by geophysical methods or drilling (Masaytis, 1975; Masaytis and others, 1978; 1980).

Meteoritic components or enrichment in meteoric-signature elements have been identified in the following 18 probable impact structures (Grieve and others, 1981; Grieve, 1982):
North America
  Canada
    Clearwater Lake East, Quebec
    Gow Lake, Saskatchewan
    Nicholson Lake, N.W. Territories
    Wanapitei Lake, Ontario
South America
  Monturaqui Crater, Chile
Australia
  Strangways, Northern Territory
Europe
  Chassenon Crater, France
  Lake Lappajarvi, Finland
  Lake Mien, Sweden
  Lake Saaksjarvi, Finland
  Obolon, Ukrainian SSR, USSR
  Rieskessel, Germany
Asia
  Kara, RSFSR, USSR
  Popigay, USSR
  Sobolev, USSR
  Tabun-Khara-Obo, Mongolia
  Zhamanshin, KSSR, USSR
Africa
  Aouelloul Crater, Mauritania
Nomenclature

At present, the naming of terrestrial impact structures is not standardized. Many impact sites are known only by a local geographic name of unknown designation. Where a qualifier has been added to the geographic name, no orderly system of rules is being followed, such as been devised by the Working Group for Planetary Systems Nomenclature of the International Astronomical Union for the surficial features of other planets. Some qualifiers imply a topographic feature: lake, bay, island, area, mound, or crater. Others have a vague geologic structural connotation: disturbance, dome, basin, or ring. Redundant meanings in adding English names to foreign designations are common: i.e. in the name Lake Janis'yarvi (Karelian SSR), the Baltic name "Jarvi" means "Lake". Further, nothing is more confusing to the nonspecialist than to name as "crater" an impact structure so completely eroded that all morphological and most structural evidence of the original impact depression are lacking. A case in point is Chassenon Crater, France, where "crater" has a genetic connotation, and is not taken in its usual topographic or structural sense. The term "astrobleme", applied by Dietz (1961) to circular features that are "obliterated craters made by a meteorite or the head of a comet", should be reserved for deeply eroded impact structures.

Several terrestrial impact structures have more than one name or spelling. The names adopted in this compilation follow U.S. Geological Survey usage as established by Freeberg (1966, 1969); Grieve's (1982) spelling is used for craters not listed by Freeberg. Alternate names appear in the individual entries and in an index. None of the names in this compilation were checked for official spelling and usage against national gazetteers or those of the U.S. Department of State.
Locations of Impact Sites

Locations of the structures are shown on sketch maps of six continents: North America, South America, Australia, Europe, Asia, and Africa (figs. 1 through 6). The geographic coordinates of each structure are given in the tables that precede the bibliographies of structures for each continent. The locations of a few structures in previous lists, including that of Grieve (1982), have been corrected if they have been plotted on a recently published map, or if a more accurate geographic description has since been supplied.

Iron Meteorites, Tektites and Microtektites, and Impact Glass

Iron meteorites associated with proven impact craters are referenced under pertinent impact structures according to the citations by Buchwald (1975). It is now generally agreed that tektites are of terrestrial origin, and that they originate at impact sites. Tektite literature is immense, and rather than include a bulky, yet incomplete bibliography of tektites in this compilation, selected references on moldavites were added to the Rieskessel bibliography, those on Ivory Coast tektites and microtektites to that of Lake Bosumtwi, Ghana, and those on Libyan Desert Glass (LDG) to that of the two Libyan impact structures: Oasis and BP. Similarly, references to Aouelloul glass and zhamanshinite will be found respectively in the bibliographies of Aouelloul Crater, Mauritania, and Zhamanshin, Kazakh SSR.

Earlier Bibliographies

Grieve's list of 1982, although authoritative, is only the most recently published of many lists, catalogues, and summary bibliographies of terrestrial impact structures. This compilation would be incomplete without guiding users to at least some of the, including the most comprehensive one for the USSR (Masaytis and others, 1980). So, a bibliography of impact-structure bibliographies is also included in the compilation, supplemented by a
bibliography of early articles on cryptovolcanic and cryptoexplosion structures, and one on astrons (Norman and Churwu-Ike, 1977), those enigmatic, very large, circular features reported from time to time on the Earth's surface, but as yet of unknown origin, and unstudied because of their very large dimensions.

Serials

Serials cited in this bibliography are not listed separately. The need for such a list is obviated by complete titles being given in the citations by authors, as against the abbreviated titles in Freeberg's 1966 bibliography and its 1969 supplement. The issuing agency or commercial publisher is indicated. An author index is included at the end of this compilation.

Conclusion

The number of known terrestrial impact structures will undoubtedly expand more dramatically in the next 30 years than in the past 30. Vast areas of all continents still remain inadequately surveyed for impact structures, even where the geologic environment is mapped at an adequate scale. Most of the South American and African continents is blank with respect to the actual density of preserved impact structures, as are the northwestern part of North America, eastern Australia, northeastern Europe, and all of China and northeast Asia (figs. ). Moreover, additional impact structures may be discovered from now on at a higher rate than in the past, as future searches become more systematic rather than merely fortuitous or a result of serendipity. At the moment, interested geologists and astronomers make a deliberate attempt to match the predicted crater density on land with changing impact-cratering rates in Precambrian and Phanerozoic times on one hand, and the rates of crater erosion and preservation on the other (Fedynskiy and Khryanina, 1976; Dachille, 1977; Grieve and Dence, 1979; Shoemaker and others,

Acknowledgments

This research was funded by the NASA Geophysics-Geochemistry Program Office from 1974 to 1984 under NASA contract no. W13, 130 under the sponsorships of William Quaide, Chief of Geophysics & Geochemistry program and Joseph M. Boyce, Chief of Planetary Geology. The project title was Atlas of terrestrial impact craters, basins, and astroblemes.

This study was initiated by Robert Bryson of the Lunar Programs Office in 1974 and continued under NASA contract No. W13,130.
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craters: Meteoritics, v. 11, no. 4, p. 270-271, 1 fig.

Dietz, R. S., 1959, Point d'impact des asteroides comme origine des bassins
oceaniques: Une hypothese [in French]: Colloque International du Centre
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cryptoexplosive, etc. [Contribution to the establishment of a list of
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BIBLIOGRAPHIES OF TERRESTRIAL IMPACT STRUCTURES: IMPACT SITES

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Table 1a. North America: Impact Structures (in alphabetical order)

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<thead>
<tr>
<th>Name</th>
<th>Geographic coordinates</th>
<th>DMC*</th>
<th>Landsat Path/Row</th>
<th>Landsat image ID No. and date of Acquisition</th>
<th>Diameter (km)</th>
<th>Age (m.y.)</th>
<th>Target Rock</th>
<th>Pres.</th>
<th>Morph.</th>
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<td>Barringer Crater, Alternate names: Canyon Diablo, Ninninger Crater, Meteor Crater Coconino County, Arizona</td>
<td>35°02'N 111°01'W</td>
<td>G-19</td>
<td>039/035</td>
<td>1103-17313 Nov. 3, 1972</td>
<td>1.2</td>
<td>0.011</td>
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<td>Haviland Crater, Kiowa County, Kansas</td>
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<td>031/034</td>
<td>1257-16404 April 6, 1973</td>
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<td>Odessa Craters, Ector County, Texas</td>
<td>31°48'N 102°30'W</td>
<td>G-19</td>
<td>032/038</td>
<td>1348-16532 July 6, 1973</td>
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Proven impact craters

Probable impact craters and astroblomes

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<th>Target Rock</th>
<th>Pres.</th>
<th>Morph.</th>
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<td>H-23</td>
<td>030/040</td>
<td>1130-16431 Nov. 30, 1972</td>
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<td>&lt;40</td>
<td>Sed</td>
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<td>37°30'N 91°23'W</td>
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<td>1036-16165 Aug. 8, 1972</td>
<td>5.6</td>
<td>320±80</td>
<td>Sed</td>
<td>6</td>
<td>C</td>
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<tr>
<td>Necaturville Disturbance Camden County, Missouri</td>
<td>37°54'N 92°43'W</td>
<td>G-20</td>
<td>027/034</td>
<td>1073-16224 Oct. 4, 1972</td>
<td>6</td>
<td>&lt;300</td>
<td>Sed (Cry)</td>
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<td>Flynn Creek structure, Jackson County, Tennessee</td>
<td>36°16'N 85°37'W</td>
<td>G-21</td>
<td>022/035</td>
<td>1086-15544 Oct. 17, 1972</td>
<td>3.8</td>
<td>360±20</td>
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<td>1089-16050 Oct. 19, 1972</td>
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<td>Longitude</td>
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<td>Manson structure, Calhoun County, Iowa</td>
<td>42°35'N</td>
<td>94°31'W</td>
<td>F-17</td>
<td>029/031</td>
<td>1291-16335 May 10, 1973</td>
<td>32</td>
<td>&lt;70</td>
<td>Sed&amp;Cry</td>
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<td>Middlebort Basin, Bell County, Kentucky</td>
<td>36°37'N</td>
<td>83°44'W</td>
<td>G-21</td>
<td>020/035</td>
<td>1084-15431 Oct. 15, 1972</td>
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<td>300</td>
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<td>102°30'W</td>
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<td>036/027</td>
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<td>200</td>
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<td>G-21</td>
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<td>032/039</td>
<td>1276-16543 April 25, 1973</td>
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<td>Upheaval Dome, San Juan County, Utah</td>
<td>38°27'N</td>
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<td>G-19</td>
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<td>1769-17213 Aug. 31, 1974</td>
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*ONC: Operational Navigation Chart, 1:1,000,000 scale, National Ocean Survey.

Grieve, R. A. F., 1982, Table 2


Pres: State of Preservation: 1-ejecta largely preserved, 2-ejecta partly preserved, 3-ejecta removed, rim partly preserved, 4-rim largely eroded, crater-fill products preserved, 5-crater-fill products partly preserved, 6-only remnants of crater-fill preserved, crater floor exposed, 7-crater floor removed, substructure exposed.

Morph: Morphology: S-simple crater, C-complex structure with central uplift, Cr-Complex structure with ring form.

Largest crater in a field of 3 craters.
Table 1b. North America: Impact Structures (in order of increasing latitude)

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<tr>
<th>Name</th>
<th>Geographic coordinates</th>
<th>OMC*</th>
<th>Landsat Path/Row</th>
<th>Landsat image ID No. and date of Acquisition</th>
<th>Diameter</th>
<th>Age (m.y.)</th>
<th>Target Rock</th>
<th>Pres.</th>
<th>Morph.</th>
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<tr>
<td>Odessa Craters, Ector County, Texas</td>
<td>31°48'N 102°30'W</td>
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<td>1103-17330 Nov. 3, 1972</td>
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<td>Haviland Crater, Kiowa County, Kansas</td>
<td>37°35'N 99°10'W</td>
<td>G-20</td>
<td>031/034</td>
<td>1257-16404 April 6, 1973</td>
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<td>1130-16431 Nov. 30, 1972</td>
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<td>Flynn Creek structure, Jackson County, Tennessee</td>
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<td>1086-15544 Oct. 17, 1972</td>
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<td>1105-16004 Nov. 6, 1972</td>
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<td>Cr</td>
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<td>Middlesboro Basin, Bell County, Kentucky</td>
<td>36°37'N 83°44'W</td>
<td>G-21</td>
<td>020/035</td>
<td>1084-15431 Oct. 15, 1972</td>
<td>6</td>
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<td>Crooked Creek structure, Crawford County, Missouri</td>
<td>37°50'N 91°23'W</td>
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<td>1036-16165 Aug. 28, 1972</td>
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Proven impact craters

Probable impact craters and astroblemes

(Grieve, R. A. F., 1982, Tables 1 and 2)
Table 1b (Continued)

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<th>Location</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Diameter</th>
<th>Crater Type</th>
<th>Count</th>
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<th>Ref 2</th>
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<td>37°54'N</td>
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<td>036/027</td>
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*ONC: Operational Navigation Chart, 1:1,000,000 scale, National Ocean Survey.

Grieve, R. A. F., 1982, Table 2

Sed-Sedimentary, Cry-Crystalline, ( )-minor.
Pres: State of Preservation: 1-ejecta largely preserved, 2-ejecta partly preserved, 3-ejecta removed, rim partly preserved, 4-rim largely eroded, crater-fill products preserved, 5-crater-fill products partly preserved, 6-only remnants of crater-fill preserved, crater floor exposed, 7-crater floor removed, substructure exposed.
Morph: Morphology: 5-simple crater, C-complex structure with central uplift, Cr-Complex structure with ring form.
Largest crater in a field of 3 craters.
Table 1c. North America: Impact Structures (in order of decreasing diameter) USA

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<th>Landsat Path/Row</th>
<th>Landsat image ID No. and date</th>
<th>Diameter (km)</th>
<th>Age (m.y.)</th>
<th>Target Rock</th>
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<td>G-21</td>
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<td>1378-16144 Aug. 5, 1973</td>
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<td>039/033</td>
<td>1769-17213 Aug. 31, 1974</td>
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*OFC: Operational Navigation Chart, 1:1,000,000 scale, National Ocean Survey.

Grieve, R. A. F., 1982, Table 2

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Largest crater in a field of 3 craters.
<table>
<thead>
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<th>Name</th>
<th>Geographic coordinates</th>
<th>OMC*</th>
<th>Landsat Path/Row</th>
<th>Landsat image ID No, and date of Acquisition</th>
<th>Diameter (km)</th>
<th>Age (m.y.)</th>
<th>Target Rock</th>
<th>Pres. Morph.</th>
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<td>Barringer Crater,</td>
<td>35°02'N 111°01'W</td>
<td>G-19</td>
<td>039/035</td>
<td>Nov. 3, 1972</td>
<td>1103-17313</td>
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<td>Alternate names: Canyon Diablo, Ninninger Crater, Meteor Crater, Coconino County, Arizona</td>
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<tr>
<td>Probable impact craters and astroblemes detectable on Landsat MSS images</td>
<td></td>
<td></td>
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<tr>
<td>Red Wing Creek, McKenzie County, North Dakota</td>
<td>47°40'N 102°30'W</td>
<td>F-17</td>
<td>036/027</td>
<td>Oct. 1, 1976</td>
<td>2618-16504</td>
<td>9</td>
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<td>Wells Creek area, Stewart County, Tennessee</td>
<td>36°23'N 87°40'W</td>
<td>G-20</td>
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<td>Nov. 6, 1972</td>
<td>1105-16004</td>
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<td>Serpent Mound structure, Adams County, Ohio</td>
<td>39°02'N 83°25'W</td>
<td>G-21</td>
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<td>Nov. 3, 1972</td>
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<td>Crooked Creek structure, Crawford County, Missouri</td>
<td>37°50'N 91°23'W</td>
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<td>026/034</td>
<td>Aug. 28, 1972</td>
<td>1036-16165</td>
<td>5.5</td>
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(Grieve, R. A. F., 1982, Tables 1 and 2)
Table 1d (Continued)
Proven impact craters not detectable on Landsat MSS images

| Odessa Craters, Ector County, Texas | 31°48'N 102°30'W | G-19 H-23 | 032/038 1348-16532 | 0.168 July 6, 1973 |
| Harland Crater, Kiowa County, Kansas | 37°35'N 99°10'W | G-20 H-16 | 031/034 1257-16404 | 0.011 April 6, 1973 |

Probable impact craters and astroblemes not detectable on Landsat MSS images

| Bee Bluff, Alternate name: Uvalde Zavala County, Texas | 29°02'N 99°51'W | H-23 G-19 | 030/040 1130-16431 | 2.4 <40 Sed 2 S |
| Calhoun County, Iowa | 42°35'N 94°31'W | F-17 G-19 | 029/031 1291-16335 | 32 <70 Sed&Cry 4 C |
| Marquette County, Wisconsin | 43°58'N 89°32'W | F-18 G-19 | 026/029 1378-16144 | May 10, 1973 |
| Newton County, Indiana | 40°45'N 87°25'W | F-18 G-19 | 024/032 1088-16050 | Oct. 5, 1972 |
| Camden County, Missouri | 37°54'N 92°43'W | G-20 G-19 | 027/034 1073-16224 | Oct. 4, 1972 |
| Jackson County, Tennessee | 36°16'N 85°37'W | G-20 G-19 | 022/035 1086-15544 | 3.8 360±20 Sed 3 C |

*OMC: Operational Navigation Chart, 1:1,000,000 scale, National Ocean Survey.*

Grieve, R. A. F., 1982, Table 2

Sed-Sedimentary, Cry-Crystalline, (?)-minor.

Pres: State of Preservation: 1-ejecta largely preserved, 2-ejecta partly preserved, 3-ejecta removed, rim partly preserved, 4-rim largely eroded, crater-fill products preserved, 5-crater-fill products partly preserved, 6-only remnants of crater-fill preserved, crater floor exposed, 7-crater floor removed, substructure exposed.

Morph: Morphology: S-simple crater, C-complex structure with central uplift, Cr-Complex structure with ring form. Largest crater in a field of 3 craters.
U.S.A.
Barringer Crater
(Alternate names: Canyon Diablo, Winninger Crater, Meteor Crater, Coon Mtn., Coon Butte)
Coconino County, Arizona

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Commission).
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U.S.A.
Flynn Creek Structure,
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U.S.A.
Uvalde
(Alternate name: Bee Bluff)
Zavala County, Texas

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*ONC: Orbiter Note Card

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Table 2a (Continued)

*ONC: Operational Navigation Chart, 1:1,000,000 scale, National Ocean Survey.

Grieve, R. A. F., 1982, Table 2

Sed-Sedimentary, Cry-Crystalline, ()-minor.

Pres: State of Preservation: 1-ejecta largely preserved, 2-ejecta partly preserved, 3-ejecta removed, rim partly preserved, 4-rim largely eroded, crater-fill products preserved, 5-crater-fill products partly preserved, 6-only remnants of crater-fill preserved, crater floor exposed, 7-crater floor removed, substructure exposed.

Morph: Morphology: 5-simple crater, C-complex structure with central uplift, Cr-Complex structure with ring form.
Table 2b. North America: Impact Structures (in order of increasing latitude)
Canada

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<th>Morph.</th>
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<td>1443-15325, Oct. 9, 1973</td>
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<td>1265-15465, April 14, 1973</td>
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Probable impact craters and asteroids.
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*ONC: Operational Navigation Chart, 1:1,000,000 scale, National Ocean Survey. |

Grieve, R. A. F., 1982, Table 2

Sed-Sedimentary, Cry-Crystalline, ( )-minor.

Pres: State of Preservation: 1-ejecta largely preserved, 2-ejecta partly preserved, 3-ejecta removed, rim partly preserved, 4-rim largely eroded, crater-fill products preserved, 5-crater-fill products partly preserved, 6-only remnants of crater-fill preserved, crater floor exposed, 7-crater floor removed, substructure exposed.

Morph: Morphology: 5-simple crater, C-complex structure with central uplift, Cr-Complex structure with ring form.
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<td>2.7</td>
<td>100±50</td>
<td>Cry</td>
<td>4</td>
<td></td>
<td></td>
</tr>
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<td></td>
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<td></td>
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<tr>
<td>Holleford Crater, Lanark County, Ontario</td>
<td>44°28'N</td>
<td>76°38'W</td>
<td>1027-15231</td>
<td>2</td>
<td>550±100</td>
<td>Sed(Cry)</td>
<td>4</td>
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Table 2c (Continued)

Steen River structure, Alberta
59°31'N 117°38'W

*ONC: Operational Navigation Chart, 1:1,000,000 scale, National Ocean Survey.

Grieve, R. A. F., 1982, Table 2

Sed-Sedimentary, Cry-Crystalline, ( )-minor.

Pres: State of Preservation: 1-ejecta largely preserved, 2-ejecta partly preserved, 3-ejecta removed, rim partly preserved, 4-rim largely eroded, crater-fill products preserved, 5-crater-fill products partly preserved, 6-only remnants of crater-fill preserved, crater floor exposed, 7-crater floor removed, substructure exposed.

Morph: Morphology: 5-simple crater, C-complex structure with central uplift, Cr-Complex structure with ring form.
<table>
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<tr>
<th>Name</th>
<th>Geographic coordinates</th>
<th>OLC</th>
<th>Landsat Path/Row</th>
<th>Landsat image ID No. and date of Acquisition</th>
<th>Diameter km</th>
<th>Age m.y.</th>
<th>Target Rock</th>
<th>Pres.</th>
<th>Morph.</th>
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<tr>
<td>New Quebec Crater, Alternate names: Chubb Crater, Ungava Crater, Ungava, Quebec</td>
<td>61°17'N 73°40'W</td>
<td>D-15</td>
<td>021/017</td>
<td>2081-15300 April 13, 1975</td>
<td>3.2</td>
<td>5</td>
<td>Cry</td>
<td>3</td>
<td>S</td>
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<td>Haughton Dome, Devon Island, District of Franklin, Northwest Territories</td>
<td>75°22'N 89°40'W</td>
<td>B-7</td>
<td>045/007</td>
<td>1253-17555 April 2, 1973</td>
<td>20</td>
<td>15</td>
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<td>2</td>
<td>C</td>
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<td>Wanapitei Lake, Ontario</td>
<td>46°44'N 80°44'W</td>
<td>F-18</td>
<td>021/028</td>
<td>1265-15465 April 14, 1973</td>
<td>8.5</td>
<td>37±2</td>
<td>Cry</td>
<td>5</td>
<td>C</td>
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<td>Mistassin Lake, Labrador, Newfoundland</td>
<td>55°53'N 63°18'W</td>
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<td>1183-14455 Jan. 22, 1973</td>
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<td>38±4</td>
<td>Cry</td>
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<td>West Hawk Lake, Manitoba</td>
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<td>E-17</td>
<td>032/025</td>
<td>1438-16462 Oct. 4, 1973</td>
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<td>Cry</td>
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<td>Deep Bay, Reindeer Lake, Saskatchewan</td>
<td>56°24'N 102°59'W</td>
<td>D-13</td>
<td>039/021</td>
<td>1859-17133 Nov. 29, 1974</td>
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<td>100±50</td>
<td>Cry</td>
<td>3</td>
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<td>Gow Lake, Saskatchewan</td>
<td>56°27'N 104°29'W</td>
<td>D-13</td>
<td>041/021</td>
<td>1825-17262 Oct. 26, 1974</td>
<td>5</td>
<td>&lt;200</td>
<td>Cry</td>
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<tr>
<td>Manicouagan-Mushalagan Lakes area, Quebec</td>
<td>51°23'N 68°42'W</td>
<td>E-18</td>
<td>014/024</td>
<td>1438-15024 Oct. 4, 1973</td>
<td>70</td>
<td>210±4</td>
<td>(Sed)Cry</td>
<td>5</td>
<td>Cr</td>
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<tr>
<td>Clearwater Lakes, Quebec</td>
<td>56°10'N 74°20'W</td>
<td>D-15</td>
<td>020/021</td>
<td>1156-15374 Dec. 26, 1972</td>
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<td>290±20</td>
<td>(Sed)Cry</td>
<td>4</td>
<td>C</td>
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<tr>
<td>Ile Rouleau, Quebec</td>
<td>50°41'N 73°53'W</td>
<td>E-18</td>
<td>017/025</td>
<td>2095-15102 April 27, 1975</td>
<td>4</td>
<td>&lt;300</td>
<td>Sed</td>
<td>6</td>
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Table 2d (Continued)

<table>
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<th>Location</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Date/Time</th>
<th>Age</th>
<th>Diameter</th>
<th>Type</th>
<th>Color</th>
<th>Comment</th>
</tr>
</thead>
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<tr>
<td>Pilot Lake, District of Mackenzie, Northwest Territories</td>
<td>60°17'N 111°01'W</td>
<td>D-13 047/018</td>
<td>July 3, 1973</td>
<td>1345-18110</td>
<td>6 &lt;300</td>
<td>Cry</td>
<td>6 C?</td>
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<tr>
<td>Slate Islands, Ontario</td>
<td>48°40'N 87°00'W</td>
<td>E-17 026/026</td>
<td>Aug. 16, 1976</td>
<td>2572-15541</td>
<td>30 350</td>
<td>(Sed)Cry</td>
<td>6 C</td>
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<tr>
<td>Lac La Moine, Quebec</td>
<td>57°26'N 66°36'W</td>
<td>D-15 014/020</td>
<td>Aug. 11, 1973</td>
<td>1384-15020</td>
<td>8 400</td>
<td>Cry</td>
<td>7 C</td>
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<td>Lac Couture, Quebec</td>
<td>60°08'N 75°18'W</td>
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<td>July 10, 1974</td>
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<td>8 420</td>
<td>Cry</td>
<td>6 C</td>
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<tr>
<td>Sudbury Basin, Ontario</td>
<td>46°36'N 81°11'W</td>
<td>F-18 021/028</td>
<td>April 14, 1973</td>
<td>1265-15465</td>
<td>140 1,840±150</td>
<td>Cry</td>
<td>6 C</td>
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<tr>
<td>St. Martin, Manitoba</td>
<td>51°47'N 98°33'W</td>
<td>E-17 034/024</td>
<td>July 21, 1974</td>
<td>1728-16503</td>
<td>23 225±40</td>
<td>Sed&amp;Cry</td>
<td>4 C</td>
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<tr>
<td>Charlevoix Structure, Alternate names: La Malbaie, Quebec</td>
<td>47°32'N 70°18'W</td>
<td>F-19 014/027</td>
<td>Sept. 21, 1972</td>
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<td>46 360±25</td>
<td>(Sed)Cry</td>
<td>6 C</td>
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<td>Brent Crater, Nipissing County, Ontario</td>
<td>46°05'N 78°29'W</td>
<td>F-18 019/028</td>
<td>Oct. 9, 1973</td>
<td>1443-15325</td>
<td>3.8 450±30</td>
<td>Cry</td>
<td>4 S</td>
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Probable impact craters and astroblemes not detectable on Landsat MSS images:

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<thead>
<tr>
<th>Location</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Date/Time</th>
<th>Age</th>
<th>Diameter</th>
<th>Type</th>
<th>Color</th>
<th>Comment</th>
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<tr>
<td>Carswell Lake structure, Saskatchewan</td>
<td>56°27'N 109°30'W</td>
<td>D-13 044/015</td>
<td>June 7, 1974</td>
<td>1684-17472</td>
<td>37 485±50</td>
<td>Sed&amp;Cry</td>
<td>7 C</td>
<td></td>
</tr>
<tr>
<td>Holleford Crater, Lanark County, Ontario</td>
<td>44°28'N 76°38'W</td>
<td>F-19 017/029</td>
<td>Aug. 19, 1972</td>
<td>1027-15231</td>
<td>2 550±100</td>
<td>Sed(Cry)</td>
<td>4 S</td>
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<tr>
<td>Steen River structure, Alberta</td>
<td>59°31'N 117°38'W</td>
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135
Table 2d (Continued)

*OFC: Operational Navigation Chart, 1:1,000,000 scale, National Ocean Survey.

Grieve, R. A. F., 1982, Table 2

<table>
<thead>
<tr>
<th>Sedimentary</th>
<th>Crystalline</th>
<th>( )-minor</th>
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<tbody>
<tr>
<td>Pres: State of Preservation:</td>
<td>1-ejecta largely preserved, 2-ejecta partly preserved, 3-ejecta removed, rim partly preserved, 4-rim largely eroded, crater-fill products preserved, 5-crater-fill products partly preserved, 6-only remnants of crater-fill preserved, crater floor exposed, 7-crater floor removed, substructure exposed.</td>
<td></td>
</tr>
<tr>
<td>Morph: Morphology:</td>
<td>5-simple crater, C-complex structure with central uplift, Cr-Complex structure with ring form.</td>
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</tbody>
</table>
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Alternate name: La Malbaie
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Newfoundland, Labrador

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Alternate names: Chubb Crater,
Ungava Crater
Ungava Peninsula, Quebec

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Sed-Sedimentary, Cry-Crystalline, ( )-minor.

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**Table 3d. South America: Impact Structures (in order of increasing geologic age)**

Probable impact craters and astroblèmes detectable on Landsat MSS images

Probable impact crater barely detectable on Landsat MSS images

Proven impact craters not detectable on Landsat MSS images

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*ONC: Operational Navigation Chart, 1:1,000,000 scale, National Ocean Survey.*

Grieve, R. A. F., 1982, Table 2

**Pres:** State of Preservation: 1-ejecta largely preserved, 2-ejecta partly preserved, 3-ejecta removed, rim partly preserved, 4-rim largely eroded, crater-fill products preserved, 5-crater-fill products partly preserved, 6-only remnants of crater-fill preserved, crater floor exposed, 7-crater floor removed, substructure exposed.

**Morph:** Morphology: 5-simple crater, 6-complex structure with central uplift, Cr-Complex structure with ring form.

Largest crater in a field of 20 craters.
South America
Argentina, Gran Chaco Gualamba
Campo del Cielo Craters

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Brazil, Matto Grosso
Araguainha Dome

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Proven meteorite impact craters

Probable impact craters and astroblemes
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<th>&lt;1,585±5</th>
<th>Sed&amp;Cry</th>
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**GEO:** Operational Navigation Chart, 1:1,000,000 scale, National Ocean Survey.

**Grieve, R. A. F., 1982, Table 2**

1. **Sed:** Sedimentary, **Cry:** Crystalline, ( )-minor.
2. **Pres:** State of Preservation: 1-ejecta largely preserved, 2-ejecta partly preserved, 3-ejecta removed, rim partly preserved, 4-rim largely eroded, crater-fill products preserved, 5-crater-fill products partly preserved, 6-only remnants of crater-fill preserved, crater floor exposed, 7-crater floor removed, substructure exposed.
3. **Morph:** Morphology: 5-simple crater, C-complex structure with central uplift, C-complex structure with ring form.
4. **Diameter of largest crater in a field of 14 craters:**
5. **Location of Kelly West matches published geographic description (Tonkin, 1973).**
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</table>

Proven meteorite impact craters

| Liverpool, Northern Territory                 | 12°24'S 134°03'E       | M-13| 111/069         | 30003-30027 Apr. 7, 1978                     | 1.6      | 150±70   | Sed         | 3     | S      |                                        |
| Strangways, Northern Territory                | 15°12'S 123°35'E       | M-13, M-14 | 111/070 | 2370-00255 Jan. 27, 1976 | 24        | <600     | Sed(Cry)    | 5     | C      |                                        |
| Spider, Western Australia                     | 16°30'S 126°00'E       | P-13| 115/072         | 1378-01031 Aug. 15, 1973                     | 5        | ?        | Sed         | 7     | C      |                                        |
| Goat Paddock, Western Australia               | 18°20'S 126°40'E       | P-13| 115/073         | 1414-01030 Sept. 10, 1973                    | 5        | <50      | Sed         | 3     | C      |                                        |
| Kelly West1, Northern Territory               | 19°57'S 133°56'E       | P-13| 110/074         | 1085-00354 Oct. 16, 1972                     | 2.5      | <550     | Sed         | 7     | ?      |                                        |
| Gosses Bluff, Northern Territory              | 23°50'S 132°18'E       | Q-13| 110/077         | 1247-00375 Mar. 27, 1973                     | 22       | 130±6    | Sed         | 6     | C      |                                        |
Table 4b (Continued)

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*ONC: Operational Navigation Chart, 1:1,000,000 scale, National Ocean Survey.

Grieve, R. A. F., 1982, Table 2

Sed-Sedimentary, Cry-Crystalline, ( )-minor.

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¹ This site is a suspected impact structure based on geological evidence.
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*Diameter of largest crater in a field of 14 craters.

1Location of Kelly West matches published geographic description (Tonkin, 1973).
## Table 4d. Australia: Impact Structures (in order of increasing geologic age)

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Table 4d (Continued)

Proven impact craters not detectable on Landsat MSS images

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<th>MSS Number</th>
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<td>117°05'E</td>
<td>120/079</td>
<td>31572-01270</td>
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*ONC: Operational Navigation Chart, 1:1,000,000 scale, National Ocean Survey.

Grieve, R. A. F., 1982, Table 2

Sed-Sedimentary, Cry-Crystalline, ( )-minor.
Pres: State of Preservation: 1-ejecta largely preserved, 2-ejecta partly preserved, 3-ejecta removed, rim partly preserved, 4-rim largely eroded, crater-fill products preserved, 5-crater-fill products partly preserved, 6-only remnants of crater-fill preserved, crater floor exposed, 7-crater floor removed, substructure exposed.
Morph: Morphology: S-simple crater, C-complex structure with central uplift, Cr-Complex structure with ring form.
1Diameter of largest crater in a field of 14 craters.
2Location of Kelly West matches published geographic description (Tonkin, 1973).
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<th>Landsat ID No. and date of Acquisition</th>
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*ONC: Operational Navigation Chart, 1:1,000,000 scale, National Ocean Survey.

Grieve, R. A. F., 1982, Table 2


Pres: State of Preservation: 1-ejecta largely preserved, 2-ejecta partly preserved, 3-ejecta removed, rim partly preserved, 4-rim largely eroded, crater-fill products preserved, 5-crater-fill products partly preserved, 6-only remnants of crater-fill preserved, crater floor exposed, 7-crater floor removed, substructure exposed.

Morph: Morphology: 1-simple crater, C-complex structure with central uplift, Cr-Complex structure with ring form.

Largest crater in field of 7 craters

1Geographic coordinates of USSR impact structures, adjusted to match the approximate centers of large structures (Puchezh-Katunki, Mishinogorsk), or to conform to scant geographic descriptions in the Russian literature (Karla). The geographic coordinates of impact structures occupied by lakes are those of the lake centers.
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*ONC: Operational Navigation Chart, 1:1,000,000 scale, National Ocean Survey.*

Grieve, R. A. F., 1982, Table 2

Sed-Sedimentary, Cry-Crystalline, ( )-minor.
Pres: State of Preservation: 1-ejecta largely preserved, 2-ejecta partly preserved, 3-ejecta removed, rim partly preserved, 4-rim largely eroded, crater-fill products preserved, 5-crater-fill products partly preserved, 6-only remnants of crater-fill preserved, crater floor exposed, 7-crater floor removed, substructure exposed.
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Largest crater in field of 7 craters.
Geographic coordinates of USGS impact structures, adjusted to match the approximate centers of large structures (Puchezh-Katunki, Nishinogorsk), or to conform to scant geographic descriptions in the Russian literature (Karla). The geographic coordinates of impact structures occupied by lakes are those of the lake centers.
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Grieve, R. A. F., 1982, Table 2

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**Probable impact craters and astroblemes barely detectable on Landsat MSS images**

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<td>Sed&amp;Cry</td>
<td>2</td>
<td>Cr</td>
</tr>
<tr>
<td><strong>Steinheim Basin, Germany</strong></td>
<td>48°41'N 10°04'E</td>
<td>E-2</td>
<td>208/026</td>
<td>1309-09383 May 28, 1973</td>
<td>3.4</td>
<td>14.8±0.7</td>
<td>Sed</td>
<td>3</td>
<td>C</td>
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### Table 5d (Continued)

<table>
<thead>
<tr>
<th>Name</th>
<th>Lat/Long</th>
<th>Size</th>
<th>Depth</th>
<th>Occurrence</th>
<th>Impact Crater</th>
<th>Type</th>
<th>Year</th>
</tr>
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<tbody>
<tr>
<td>Chasseron Crater, (Alternate name:</td>
<td>45°49'N</td>
<td>F-1</td>
<td>214/028</td>
<td>1243-10141</td>
<td>Cry</td>
<td>6</td>
<td>C</td>
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<tr>
<td>Rochechouart), France</td>
<td>0°46'E</td>
<td></td>
<td></td>
<td>Mar. 23, 1973</td>
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<td></td>
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<tr>
<td></td>
<td>24°36'E</td>
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<td>May 5, 1978</td>
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<tr>
<td>Puchezh-Katunki Crater, RSFSR, U.S.S.R.</td>
<td>56°56'N</td>
<td>D-3</td>
<td>188/020</td>
<td>2105-07291</td>
<td>Sed&amp;Cry</td>
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<td>Cr</td>
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<td>May 7, 1975</td>
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<tr>
<td>Mishinogorsk, RSFSR, U.S.S.R.</td>
<td>58°35'N</td>
<td>D-3</td>
<td>201/019</td>
<td>2460-08382</td>
<td>Sed(Cry)</td>
<td>5</td>
<td>C</td>
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<tr>
<td></td>
<td>28°07'E</td>
<td></td>
<td></td>
<td>Apr. 26, 1976</td>
<td></td>
<td></td>
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<tr>
<td>Misarai, Lithuanian SSR, U.S.S.R.</td>
<td>54°00'N</td>
<td>E-3</td>
<td>202/022</td>
<td>2155-08503</td>
<td>Sed?</td>
<td>?</td>
<td>?</td>
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<tr>
<td></td>
<td>23°54'E</td>
<td></td>
<td></td>
<td>June 26, 1975</td>
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**Proven impact craters not detectable on Landsat MSS images**

<table>
<thead>
<tr>
<th>Name</th>
<th>Lat/Long</th>
<th>Size</th>
<th>Depth</th>
<th>Occurrence</th>
<th>Impact Crater</th>
<th>Type</th>
<th>Year</th>
</tr>
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<tbody>
<tr>
<td>Kaalijarv Craters, Estonian SSR, U.S.S.R.</td>
<td>58°24'N</td>
<td>D-3</td>
<td>204/019</td>
<td>2103-09004</td>
<td>0.11*</td>
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<tr>
<td></td>
<td>22°40'E</td>
<td></td>
<td></td>
<td>May 5, 1975</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morasko Craters, Poland</td>
<td>59°29'N</td>
<td>E-3</td>
<td>205/023</td>
<td>2104-09080</td>
<td>0.1*</td>
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<tr>
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<td>16°54'E</td>
<td></td>
<td></td>
<td>May 6, 1975</td>
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**Probable impact craters and astroblemes not detectable on Landsat MSS images**

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<th>Lat/Long</th>
<th>Size</th>
<th>Depth</th>
<th>Occurrence</th>
<th>Impact Crater</th>
<th>Type</th>
<th>Year</th>
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<tr>
<td>Ternovka, U.S.S.R.</td>
<td>51°19'N</td>
<td>F-4</td>
<td>187/024</td>
<td>2608-07160</td>
<td>6</td>
<td>?</td>
<td>?</td>
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<tr>
<td></td>
<td>42°58'E</td>
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<td></td>
<td>Sept. 21, 1976</td>
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<tr>
<td>Karla, Tatar SSR, U.S.S.R.</td>
<td>55°00'N</td>
<td>E-4</td>
<td>185/021</td>
<td>2138-07123</td>
<td>10</td>
<td>10</td>
<td>?</td>
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<td></td>
<td>48°20'E</td>
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<td></td>
<td>40°18'E</td>
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<td></td>
<td>Aug. 17, 1976</td>
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<tr>
<td>Rotmistrovka, Ukrainian SSR, U.S.S.R.</td>
<td>49°00'N</td>
<td>E-3</td>
<td>193/026</td>
<td>2074-08003</td>
<td>5</td>
<td>70</td>
<td>Cry</td>
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<td></td>
<td>32°00'E</td>
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<td>April 6, 1975</td>
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<tr>
<td>Boltyshe, Ukrainian SSR, U.S.S.R.</td>
<td>48°45'N</td>
<td>E-3</td>
<td>191/027</td>
<td>2108-07491</td>
<td>25</td>
<td>100±5</td>
<td>Cry</td>
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<td></td>
<td>32°10'E</td>
<td></td>
<td></td>
<td>May 10, 1975</td>
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<tr>
<td>Logosk, Byelorussian SSR, U.S.S.R.</td>
<td>54°12'N</td>
<td>E-3</td>
<td>198/022</td>
<td>2475-08220</td>
<td>17</td>
<td>100±20</td>
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<tr>
<td></td>
<td>27°48'E</td>
<td></td>
<td></td>
<td>May 11, 1976</td>
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Table 5d (Continued)

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<th>Location</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Event Code</th>
<th>Event Date</th>
<th>Event Time</th>
<th>Diameter (km)</th>
<th>Max. Depth (m)</th>
<th>Recurrence</th>
<th>Type</th>
<th>Height?</th>
<th>Hazard?</th>
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<tr>
<td>Zeleny Gai</td>
<td>48°07'N</td>
<td>32°09'E</td>
<td>E-3</td>
<td>191/02/03</td>
<td>May 10, 1975</td>
<td>1.4</td>
<td>120±20</td>
<td></td>
<td>?</td>
<td>?</td>
<td>S</td>
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<tr>
<td>Ukrainian SSR, U.S.R.</td>
<td>49°30'N</td>
<td>32°55'E</td>
<td>E-3</td>
<td>191/02/27</td>
<td>May 10, 1975</td>
<td>15</td>
<td>160</td>
<td>Cry</td>
<td>5</td>
<td>C</td>
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<tr>
<td>Obolcn,</td>
<td>51°40'N</td>
<td>36°00'E</td>
<td>E-4</td>
<td>192/02/24</td>
<td>Mar. 25, 1977</td>
<td>5</td>
<td>250±80</td>
<td>Sed &amp; Cry</td>
<td>5</td>
<td>C</td>
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<tr>
<td>Kjerdla</td>
<td>57°00'N</td>
<td>22°42'E</td>
<td>D-3</td>
<td>203/02/01</td>
<td>Sept. 19, 1976</td>
<td>4</td>
<td>500±50</td>
<td>Sed?</td>
<td></td>
<td>?</td>
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</tbody>
</table>

*ONC: Operational Navigation Chart, 1:1,000,000 scale, National Ocean Survey.

Grieve, R. A. F., 1982, Table 2

Sed-Sedimentary, Cry-Crystalline, ( )-minor.

Pres: State of Preservation: 1-ejecta largely preserved, 2-ejecta partly preserved, 3-ejecta removed, rim partly preserved, 4-rim largely eroded, crater-fill products preserved, 5-crater-fill products partly preserved, 6-only remnants of crater-fill preserved, crater floor exposed, 7-crater floor removed, substructure exposed.

Morph: Morphology: S-simple crater, C-complex structure with central uplift, Cr-Complex structure with ring form.

Largest crater in field of 7 craters

Geographic coordinates of USSR impact structures, adjusted to match the approximate centers of large structures (Puchezh-Katunki, Mishinogorsk), or to conform to scant geographic descriptions in the Russian literature (Karla). The geographic coordinates of impact structures occupied by lakes are those of the lake centers.
Europe
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Estonskoy SSR, Saaremaa Island
Kaalijarv Craters

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(Alternate name: Rochechouart Crater)

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Bibliography


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<th>Target Rock</th>
<th>Pres. Morph.</th>
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*ONC: Operational Navigation Chart, 1:1,000,000 scale National Ocean Survey

Grieve, R. A. F., 1982, Table 2

- Pres: State of Preservation: 1-ejecta largely preserved, 2-ejecta partly preserved, 3-ejecta removed, rim partly preserved. 4-rim largely eroded, crater-fill products preserved, 5-crater-fill products partly preserved, 6-only remnants of crater-fill preserved, crater floor exposed, 7-crater floor removed, substructure exposed.
- Morph: Morphology: 5-simple crater, C-complex structure with central uplift, Cr-Complex structure with ring form.
- 1-Larger of two craters.
- 2-Largest crater in a field of 122 craters.
- The geographic coordinates of large USSR impact structures are adjusted to match the approximate structure centers (Zhamaishin, Kara, Beyenchine-Salata, and Popigay), or to conform to the geographic description published in the Russian literature (Shunak). Sobolev is located at 137°52'E, not at 138°52'E as shown on Table 2, p. 28 (Grieve, 1982). The geographic coordinates of impact structures occupied by lakes are those of the lake centers.
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<td>Cry</td>
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<td>C</td>
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(Grieve, R. A. F., 1982, Table 2)
Table 6b (Continued)

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*OHC: Operation Chart, 1:1,000,000 scale National Ocean Survey

Grieve, R. A. F. 2, Table 2

Sed-Sedimentary, Cry-Crystalline, ( )-minor.

Pres: State of Preservation: 1-ejecta largely preserved, 2-ejecta partly preserved, 3-ejecta removed, rim partly preserved, 4-rim largely eroded, crater-fill products preserved, 5-crater-fill products partly preserved, 6-only remnants of crater-fill preserved, crater floor exposed, 7-crater floor removed, substructure exposed.

Morph: Morphology: 5-simple crater, C-complex structure with central uplift, Cr-Complex structure with ring form.

2Larger of two craters.

The geographic coordinates of large USSR impact structures are adjusted to match the approximate structures centers (Zhamanshin, Kara, Beyenchime-Salata, and Popigay), or to conform to the geographic description published in the Russian literature (Shurenk). Sobolev is located at 137°52'E, not at 138°52'E as shown on Table 2, p. 20 (Grieve, 1982). The geographic coordinates of impact structures occupied by lakes are those of the lake centers.
Table 6c. Asia: Impact Structures (in order of decreasing diameter)

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<th>Age (m.y.)</th>
<th>Target Rock</th>
<th>Pres.</th>
<th>Morph.</th>
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<td>Wabar Craters, Saudi Arabia</td>
<td>21°28'N 50°29'E</td>
<td>J-7</td>
<td>175;045</td>
<td>1438-06350</td>
<td>0.097</td>
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<tr>
<td>Sikhote Alin Craters, Primorye Territorie, U.S.S.R.</td>
<td>46°07'N 134°40'E</td>
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<td>39±9</td>
<td>Sed&amp;Cry</td>
<td>3</td>
<td>Cr</td>
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<tr>
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<td>57</td>
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<td>&lt;5</td>
<td>1.00</td>
<td>&lt;0.00001</td>
<td>0.009</td>
<td>0.0003</td>
<td>0.05</td>
<td>0.002</td>
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<tr>
<td>Patmoskii Crater, Irkutsk Oblast, Russian-SFSR, U.S.S.R.</td>
<td>59°00'N</td>
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<td>D-7</td>
<td>138/019</td>
<td>1419-02522</td>
<td>0.09</td>
<td>.0003</td>
<td>Sed</td>
<td>2</td>
<td>&lt;5</td>
<td>1.00</td>
<td>&lt;0.00001</td>
<td>0.009</td>
<td>0.0003</td>
<td>0.05</td>
<td>0.002</td>
<td>2</td>
<td>&lt;5</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Socolev, Primorye Territorie, U.S.S.R.</td>
<td>46°18'N</td>
<td>137°52'E</td>
<td>E-10</td>
<td>120/028</td>
<td>2307-01004</td>
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<td>0.002</td>
<td>Cry</td>
<td>2</td>
<td>&lt;5</td>
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*ONC: Operational Navigation Chart, 1:1,000,000 scale National Ocean Survey

Grieve, R. A. F., 1982, Table 2

- Sed-Sedimentary, Cry-Crystalline, ( )-minor.
- Pres: State of Preservation: 1-ejecta largely preserved, 2-ejecta partly preserved, 3-ejecta removed, rim partly preserved, 4-rim largely eroded, crater-fill products preserved, 5-crater-fill products partly preserved, 6-only remnants of crater-fill preserved, crater floor exposed, 7-crater floor removed, substructure exposed.
- Morph: Morphology: 5-simple crater, 6-complex structure with central uplift, 7-complex structure with ring form.
- *Larger of two craters.
- **Largest crater in a field of 122 craters.

The geographic coordinates of large USSR impact structures are adjusted to match the approximate structures centers (Zharmashin, Kara, Beyenchine-Salat, and Popigay), or to conform to the geographic description published in the Russian literature (Shunak). Socolev is located at 137°52'E, not at 138°52'E as shown on Table 2, p. 28 (Grieve, 1982). The geographic coordinates of impact structures occupied by lakes are those of the lake centers.
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<th>Landsat ID No. and date of Acquisition</th>
<th>Landsat image ID</th>
<th>Diameter (km)</th>
<th>Age (m.y.)</th>
<th>Target Rock</th>
<th>Pres.</th>
<th>Morph.</th>
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<tr>
<td>Lunar Lake, India</td>
<td>19°58'N 76°31'E</td>
<td>J-8 156/046</td>
<td>Jan. 6, 1973</td>
<td>1167-04481</td>
<td>1.83</td>
<td>0.05</td>
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<td>67°29'N 172°05'E</td>
<td>C-7 106/012</td>
<td>July 6, 1973</td>
<td>1350-23470</td>
<td>19</td>
<td>3.5±0.5</td>
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<td>47°12'N 72°58'E</td>
<td>F-6 165/027</td>
<td>Sept. 11, 1972</td>
<td>1050-05312</td>
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<td>12</td>
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<td>Tabun Khara Oso, Mongolia</td>
<td>44°06'N 109°35'E</td>
<td>F-8 138/029</td>
<td>Jan. 1, 1974</td>
<td>1527-02544</td>
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<td>&lt;30</td>
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<td>Bayanobi-Salata, Yakotsk SSR, U.S.S.R.</td>
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<td>Mar. 27, 1973</td>
<td>1247-03360</td>
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<td>&lt;65</td>
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<td>3</td>
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</table>

*Proven impact craters not detectable on Landsat MSS images*

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<th>Name</th>
<th>Geographical coordinates</th>
<th>OMC* Path/Row</th>
<th>Landsat image ID</th>
<th>Diameter (km)</th>
<th>Age (m.y.)</th>
<th>Target Rock</th>
<th>Pres.</th>
<th>Morph.</th>
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<td>Weber Craters, Saudi Arabia</td>
<td>21°28'N 50°29'E</td>
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<td>May 4, 1978</td>
<td>1438-06350</td>
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<td>Sikhola Alia Craters, Prinzipa Territorie, U.S.S.R.</td>
<td>46°07'N 134°40'E</td>
<td>F-10 121/028</td>
<td>Jun. 29, 1975</td>
<td>2524-01013</td>
<td>0.026*2</td>
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</table>
Table 6d (Continued)

| Probable impact craters and astromblems not detectable on Landsat MSS images |
|-------------------------------------------------|----------------|-----------|----------------|-----------------|------|---|
| Sobolev,                                        | 46°18'N        | E-10      | 120/028       | 2307-01004      | 0.05 | 0.002 | Cry | 2   | S  |
| Primorye Territorie, U.S.S.R.                   | 137°52'E       |           |               | Nov. 25, 1975   |      |       |     |     |    |
| Patomskii Crater                                | 59°00'N        | D-7       | 138/019       | 1419-02522      | 0.09 | .0003  | Sed | 2   | S  |
| Kara,                                          | 69°07'N        | C-4       | 182/011       | 1337-07024      | 50   | 57     | Sed | 5   | C  |

*OMC: Operational Navigation Chart, 1:1,000,000 scale National Ocean Survey

Grieve, R. A. F., 1982, Table 2

Sed-Sedimentary, Cry-Crystalline, ( )-minor.
Pres: State of Preservation: 1-ejecta largely preserved, 2-ejecta partly preserved, 3-ejecta removed, rim partly preserved, 4-rim largely eroded, crater-fill products preserved, 5-crater-fill products partly preserved, 6-only remnants of crater-fill preserved, crater floor exposed, 7-crater floor removed, substructure exposed.
Morph: Morphology: S-simple crater, C-complex structure with central uplift, Cr-Complex structure with ring form.
2Larger of two craters.
2Largest crater in a field of 122 craters.
2The geographic coordinates of large USSR impact structures are adjusted to match the approximate structures centers (Zhamanshin, Kara, Beyenchime-Salata, and Popigay), or to conform to the geographic description published in the Russian literature (Shunak). Sobolev is located at 137°52'E, not at 138°52'E as shown on Table 2, p. 28 (Grieve, 1982). The geographic coordinates of impact structures occupied by lakes are those of the lake centers.
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Saudi Arabia
Wabar (Al Hadidah) Craters

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Bibliography


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<th>Age (m.y.)</th>
<th>Target Rock</th>
<th>Pres.</th>
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(Grieve, R. A. F., 1982, Table 2)
Table 7a (Continued)

*ONC: Operational Navigation Chart, 1:1,000,000 scale, National Ocean Survey.

Grieve, R. A. F., 1982, Table 2

Sed-Sedimentary, Cry-Crystalline, ( )-minor.
Pres: State of Preservation: 1-ejecta largely preserved, 2-ejecta partly preserved, 3-ejecta removed, rim partly preserved, 4-rim largely eroded, crater-fill products preserved, 5-crater-fill products partly preserved, 6-only remnants of crater-fill preserved, crater floor exposed, 7-crater floor removed, substructure exposed.
Morph: Morphology: 5-simple crater, C-complex structure with central uplift, Cr-Complex structure with ring form.
Table 7b. Africa: Impact Structures (in order of increasing latitude)

<table>
<thead>
<tr>
<th>Name</th>
<th>Geographic coordinates</th>
<th>ONC* Path/Row</th>
<th>Landsat ID No. and date of Acquisition</th>
<th>Diameter (km)</th>
<th>Age (m.y.)</th>
<th>Target Rock</th>
<th>Pres.</th>
<th>Morph.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lake Bosumtwi, Ghana</td>
<td>6°29'N, 1°24'W</td>
<td>L-2 208/056</td>
<td>1579-09460 Feb. 22, 1974</td>
<td>10.5</td>
<td>1.3±0.2</td>
<td>Cry</td>
<td>2</td>
<td>C</td>
</tr>
<tr>
<td>Agoultou Crater, Mauritania</td>
<td>20°15'W, 12°41'W</td>
<td>J-1 218/046</td>
<td>1229-10443 Mar. 9, 1973</td>
<td>0.37</td>
<td>3.1±0.3</td>
<td>Sed</td>
<td>4</td>
<td>S</td>
</tr>
<tr>
<td>Tanoumer Crater, Mauritania</td>
<td>22°55'N, 10°24'W</td>
<td>J-2 218/044</td>
<td>1103-10431 Nov. 3, 1972</td>
<td>1.9</td>
<td>2.5±0.5</td>
<td>Cry</td>
<td>3</td>
<td>S</td>
</tr>
<tr>
<td>Oasis, Libya</td>
<td>24°35'N, 24°24'E</td>
<td>H-4 193/043</td>
<td>2488-08014 May 24, 1976</td>
<td>11.5</td>
<td>&lt;120</td>
<td>Sed</td>
<td>5</td>
<td>Cr</td>
</tr>
<tr>
<td>BP, (British Petroleum)</td>
<td>25°19'N, 24°20'E</td>
<td>H-4 193/042</td>
<td>2362-08044 Jan. 19, 1976</td>
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<td>C</td>
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<tr>
<td>Amguid Crater, Algeria</td>
<td>25°05'N, 04°23'E</td>
<td>H-2 208/042</td>
<td>1435-09431 Oct. 1, 1973</td>
<td>0.45</td>
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<td>2</td>
<td>S</td>
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<tr>
<td>Tin Bider, Algeria</td>
<td>27°36'N, 05°07'E</td>
<td>H-2 208/041</td>
<td>1435-09425 Oct. 1, 1973</td>
<td>6</td>
<td>&lt;70</td>
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<td>5</td>
<td>C</td>
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<tr>
<td>Quarkiz, Algeria-Morocco border</td>
<td>29°00'N, 07°33'E</td>
<td>H-1 216/040</td>
<td>2385-10152 Feb. 11, 1976</td>
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<td>&lt;70</td>
<td>Sed</td>
<td>3</td>
<td>C?</td>
</tr>
<tr>
<td>Talemzane Crater, Algeria</td>
<td>33°19'N, 04°02'E</td>
<td>G-1 209/037</td>
<td>2396-09334 Feb. 22, 1976</td>
<td>1.75</td>
<td>&lt;3</td>
<td>Sed</td>
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</table>

(Grieve, R. A. F., 1982, Table 2)

Probable impact craters and astroblemes.
Table 7b (Continued)

<table>
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<th>Wredefort structure, South Africa</th>
<th>27°00'S</th>
<th>Q-5</th>
<th>183/079</th>
<th>1158-07370</th>
<th>140</th>
<th>1,970±100</th>
<th>Sed&amp;cry</th>
<th>7</th>
<th>5</th>
</tr>
</thead>
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*OMC: Operational Navigation Chart, 1:1,000,000 scale, National Ocean Survey.

Grieve, R. A. F., 1982, Table 2

Sed-Sedimentary, Cry-Crystalline, ( )-minor.

Pres: State of Preservation: 1-ejecta largely preserved, 2-ejecta partly preserved, 3-ejecta removed, rim partly preserved, 4-rim largely eroded, crater-fill products preserved, 5-crater-fill products partly preserved, 6-only remnants of crater-fill preserved, crater floor exposed, 7-crater floor removed, substructure exposed.

Morph: Morphology: 5-simple crater, 6-complex structure with central uplift, Cr-Complex structure with r.ng form.
<table>
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<th>Diameter km</th>
<th>Age m.y.</th>
<th>Target Rock</th>
<th>Pres.</th>
<th>Morph.</th>
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<td>182/079</td>
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<tr>
<td>Oasis, Libya</td>
<td>24°35'N 24°24'E</td>
<td>H-4</td>
<td>193/043</td>
<td>2488-08014 May 24, 1976</td>
<td>11.5</td>
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<td>Sed</td>
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<td>Cr</td>
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<td>208/056</td>
<td>1579-09460 Feb. 22, 1974</td>
<td>10.5</td>
<td>1.3±0.2</td>
<td>Cry</td>
<td>2</td>
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<td>Tin Bider, Algeria</td>
<td>27°36'N 05°07'E</td>
<td>H-2</td>
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<td>29°00'N 07°33'W</td>
<td>H-1</td>
<td>216/040</td>
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<td>&lt;70</td>
<td>Sed</td>
<td>3</td>
<td>C?</td>
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<td>Tenoumer Crater, Mauritania</td>
<td>22°55'N 10°24'E</td>
<td>J-2</td>
<td>218/044</td>
<td>1103-10431 Nov. 3, 1972</td>
<td>1.9</td>
<td>2.5±0.5</td>
<td>Cry</td>
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<td>Talezmzane Crater, Algeria</td>
<td>33°19'N 04°02'E</td>
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<td>Sed</td>
<td>2</td>
<td>S</td>
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<tr>
<td>Amguid Crater, Algeria</td>
<td>26°05'N 04°23'E</td>
<td>H-2</td>
<td>208/042</td>
<td>1435-09433 Oct. 1, 1973</td>
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<td>&lt;0.1</td>
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Table 7c (Continued)

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<th>Aquellou Crater, Mauritanian</th>
<th>20°15'W</th>
<th>J-1</th>
<th>218/046</th>
<th>1229-10443</th>
<th>0.37</th>
<th>3.1±0.3 Sed</th>
<th>4</th>
<th>5</th>
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"ONC: Operational Navigation Chart, 1:1,000,000 scale, National Ocean Survey.

Grieve, R. A. F., 1982, Table 2

Sed-Sedimentary, Cry-Crystalline, ( )-minor.
Pres: State of Preservation: 1-ejecta largely preserved, 2-ejecta partly preserved, 3-ejecta removed, rim partly preserved, 4-rim largely eroded, crater-fill products preserved, 5-crater-fill products partly preserved, 6-only remnants of crater-fill preserved, crater floor exposed, 7-crater floor removed, substructure exposed.

Morph: Morphology: 5-simple crater, 6-complex structure with central uplift, Cr-complex structure with ring form."
### Probable impact craters and astroblemes detectable on Landsat MSS images

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<th>Geographic coordinates</th>
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<th>Diameter km</th>
<th>Age m.y.</th>
<th>Target Rock</th>
<th>Pres.</th>
<th>Morph.</th>
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<tr>
<td>Lake Bosumtwi, Ashanti, Ghana</td>
<td>6°29'N</td>
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<td>1579-09460</td>
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<td>1.3±0.2</td>
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<td>209/037</td>
<td>2396-09334</td>
<td>Feb. 22, 1976</td>
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<td>&lt;3</td>
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<td>Tin Bider, Algeria</td>
<td>27°36'N, 05°07'E</td>
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<td>208/041</td>
<td>1435-09425</td>
<td>Oct. 1, 1973</td>
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<td>&lt;70</td>
<td>Sed</td>
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<td>Ouarkziz, Algeria-Morocco border</td>
<td>29°00'N, 07°33'W</td>
<td>H-1</td>
<td>216/040</td>
<td>2385-10152</td>
<td>Feb. 11, 1976</td>
<td>3.5</td>
<td>&lt;70</td>
<td>Sed</td>
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<td>Qasr, Libya</td>
<td>24°35'N, 24°24'E</td>
<td>H-4</td>
<td>193/043</td>
<td>2488-08014</td>
<td>May 24, 1976</td>
<td>11.5</td>
<td>&lt;120</td>
<td>Sed</td>
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<tr>
<td>BP, (British Petroleum), Libya</td>
<td>25°19'N, 24°20'E</td>
<td>H-4</td>
<td>193/042</td>
<td>2362-08044</td>
<td>Jan. 19, 1976</td>
<td>2.8</td>
<td>&lt;120</td>
<td>Sed</td>
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<tr>
<td>138°00'S, 27°27'E, South Africa</td>
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<td>Q-5</td>
<td>183/079</td>
<td>1158-07370</td>
<td>Dec. 28, 1972</td>
<td>140</td>
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### Probable impact craters and astroblemes barely detectable on Landsat MSS images

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<th>Age m.y.</th>
<th>Target Rock</th>
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<th>Morph.</th>
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<td>Amgoud Crater, Algeria</td>
<td>26°05'N, 04°23'E</td>
<td>H-2</td>
<td>208/042</td>
<td>1435-09431</td>
<td>Oct. 1, 1973</td>
<td>0.45</td>
<td>&lt;0.1</td>
<td>Sed</td>
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<td>Auchlouvr Crater, Mauritania</td>
<td>20°15'N, 12°41'E</td>
<td>J-1</td>
<td>218/046</td>
<td>1229-10443</td>
<td>Mar. 9, 1973</td>
<td>0.37</td>
<td>3.1±0.3</td>
<td>Sed</td>
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</tbody>
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Table 7d (Continued)

*GNC: Operational Navigation Chart, 1:1,000,000 scale, National Ocean Survey.

Grieve, R. A. F., 1982, Table 2

Sed-Sedimentary, Cry-Crystalline, ( )-minnr.
Pres: State of Preservation: 1-ejecta largely preserved, 2-ejecta partly preserved, 3-ejecta removed, rim partly preserved, 4-rim largely eroded, crater-fill products preserved, 5-crater-fill products partly preserved, 6-ly remnants of crater-fill preserved, crater floor exposed, 7-crater floor removed, substructure exposed.

Morph: Morphology: S-simple crater, C-complex structure with central uplift, Cr-Complex structure with ring form.
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Mauritania
Aouelloul Crater

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Africa
Near undefined Algeria - Morocco border
Quarkziz

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This bibliography lists 105 terrestrial impact structures, of which 12 are proven structures, that is, structures associated with meteorites, and 93 are probable. Of the 93 probable structures, 18 are known to contain rocks with meteoritic components or to be enriched in meteoritic signature-elements, both of which enhance their probability of having originated by impact. Many of the structures investigated in the USSR to date are subsurface features that are completely or partly buried by sedimentary rocks. At least 16 buried impact structures have already been identified in North America and Europe. No proven nor probable submarine impact structure rising above the ocean floor is presently known; none has been found in Antarctica or Greenland.

An attempt has been made to cite for each impact structure all literature published prior to mid-1983. The structures are presented in alphabetical order by continent, and their geographic distribution is indicated on a sketch map of each continent in which they occur. They are also listed in tables in (1) alphabetical order, (2) order of increasing latitude, (3) order of decreasing diameter, and (4) order of increasing geologic age.

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