If a meteorite is seen and heard to fall and for this reason is detected and collected, it is called a fall. A find on the contrary is a meteorite which is picked up and identified because of its appearance and composition. Table 19 displays the appropriate characteristics; further details will be found in Table 23.

Table 19. Number of Meteorites, as of January 1, 1972.

<table>
<thead>
<tr>
<th></th>
<th>Falls</th>
<th>%</th>
<th>Finds</th>
<th>%</th>
<th>Total</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Chondrites</td>
<td>574</td>
<td>456</td>
<td>4.9</td>
<td>1,030</td>
<td>60.9</td>
</tr>
<tr>
<td></td>
<td>Achondrites</td>
<td>60</td>
<td>10</td>
<td>1.0</td>
<td>70</td>
<td>4.1</td>
</tr>
<tr>
<td>Stony-Irons</td>
<td>9</td>
<td>1.3</td>
<td>50</td>
<td>4.9</td>
<td>59</td>
<td>3.5</td>
</tr>
<tr>
<td>Irons</td>
<td>32</td>
<td>4.7</td>
<td>500</td>
<td>49.2</td>
<td>532</td>
<td>31.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>675</td>
<td>1,016</td>
<td>100.0</td>
<td>1,691</td>
<td>100.0</td>
</tr>
</tbody>
</table>

These data do not claim a high degree of accuracy, collected as they are from sources of widely varying authenticity and age. I do, however, believe that they represent an improvement over presently available statistics, particularly when considering stony iron and iron meteorites. Important alterations relative to Hey (1966) are summarized in Appendices 3 and 4, from which it may be seen at a glance that numerous dubious falls, synonyms, pseudometeors and unsubstantiated reports have been eliminated. The total number of iron meteorites has been reduced from 594 (Hey 1966:xv) to 532, while the total number of iron meteorite falls has been reduced from 43 to 32. The following falls have been discredited:

Elbogen, Gundaring, Helt Township, Majorca, Mariaville, Para de Minas, Patos de Minas, Puerto de Arauco, Tandil, Victoria West, Winburg and Calderilla. The reasons are given under the individual descriptions, and it is shown that Tandil is certainly, and Majorca possibly, a pseudometeorsite! Eighteen other falls listed as doubtful by Hey, e.g., Deep Springs, Raftrüti and Signal Mountain, have been shown to be finds. On the other hand, it appears that Annaheim, previously labeled a find, is qualified to be included among the falls.

Considerable changes in the Hey data are particularly apparent in the number of finds. Seventy-eight iron meteorites (Appendix 3) have been shown to have no right to separate classification. Another nine doubtful irons have been definitely proved to be pseudometeorsites (Appendix 4). The reasons for these conclusions are given in the appropriate places in the book. This "loss of meteorites" is partly counterbalanced by a number of new meteorites, not listed in Hey. These are of two kinds: (i) specimens known for some time, not previously recognized as individual iron meteorites but believed to be samples of well-known meteorites:

- New iron meteorites
  - Weight
  - Previously considered part of

- Augusta County
  - 76
  - Staunton
  - Babb's Mill,

- Babb's Mill,
  - 135
  - Troost's Iron
  - Blake's Iron
  - 3.0
  - Gibeon

- Bushman Land
  - 0.5
  - Klondike

- Gay Gulch
  - 11.6
  - Gibeon

- Karasburg
  - >100?
  - Toluca

- Paneth's Iron
  - 9.4
  - Joe Wright Mountain

- Sandtown
  - 15.9
  - Klondike

- Skookum Gulch
  - 3.6
  - Coahulla

- Smithsonian Iron
  - (ii) specimens recognized after the printing of Hey's catalog (1966), e.g., Juromenha and Zerhamra.

The irons in Appendix 2 are insufficiently known for a variety of reasons. They were (i) recently found, e.g., Aprelskij and Seymchan; (ii) poorly described although found long ago, e.g., Armanty and Barbacena; (iii) never subjected to a close study, either because they were zealously guarded, part of a private collection, or considered too small for a useful study, e.g., Cabin Creek, Hraschina, Cleburne and Albuquerque; (iv) lost before they could be described, e.g., Jalandhar and Lebedinnyi; or (v) thoroughly oxidized, thus preventing classification, e.g., Coldwater, Dorrigo and Lucky Hill.

Evidently iron meteorites of categories (i)-(iii) will eventually find their proper place in the statistics. From my cursory knowledge of the material listed in Appendix 2, I would estimate that about 40% belong in these categories and will eventually attain status of individual well-documented meteorites.

Little can be accomplished with the remaining material, of categories (iv) and (v). Some corroded specimens may be studied and classified, although only little metallic material is left. This was the case with, e.g., Ider, Wolf Creek and Kaalijarv, which were previously considered too corroded for any conclusive work. For the purpose of statistics, the number of iron meteorites in Table 19 is
taken as the 480 well-documented irons in Appendix 1 plus 40\% of the 129 insufficiently known irons, listed in Appendix 2.

As is apparent from Tables 10, 19 and 23, the number of meteorites reaching the Earth per year is small. For irons, comprising only 31 falls between 1835 and 1973, the number is in fact so small that meaningful statistical analyses are largely ruled out. The 31 registered falls correspond to one every 4.5 year, or said in a different way: Out of 17 new falls, only one is an iron. Finds of iron meteorites are, however, common because once discovered the samples are not often discarded due to their interesting appearance and density which often makes the finder believe that he has discovered an iron ore or a silver nugget. For examples, the reader is referred to the individual descriptions, such as Augusta County, Billings, Hayden Creek, Jackson County, Seelisberg and Smithland. While irons are the easiest to recognize among meteorites, achondrites stand at the opposite end of the spectrum: The data in Table 23 indicate that achondrites are similar enough to terrestrial rocks to pass largely undetected, unless found immediately after an observed fall.

Some Statistics on the Frequency of Falls

Although falls have been reported — and partially preserved — since medieval time, e.g., Elbogen and Ensisheim, we will for our purpose limit ourselves to the rather well-documented recent periods. Sorting, for example, the material from 1871 to 1970, and excluding false, unsubstantiated reports, we end with the following number of falls per decade:

<table>
<thead>
<tr>
<th>Decade</th>
<th>Number</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1871-80</td>
<td>54</td>
<td>1921-30</td>
</tr>
<tr>
<td>1881-90</td>
<td>40</td>
<td>1931-40</td>
</tr>
<tr>
<td>1891-1900</td>
<td>47</td>
<td>1941-50</td>
</tr>
<tr>
<td>1901-10</td>
<td>54</td>
<td>1951-60</td>
</tr>
<tr>
<td>1911-20</td>
<td>55</td>
<td>1961-70</td>
</tr>
</tbody>
</table>

This makes a total of 549 falls, or 5.5 falls per year, on the average, over the inhabited parts of the Earth. The surface of the Earth is $510 \times 10^6 \text{ km}^2$; of this roughly 30\% or $149 \times 10^6 \text{ km}^2$ is land, and of this again roughly $70 \times 10^6 \text{ km}^2$ has a population density above one inhabitant per km$^2$. This appears to be the minimum requirement for the reporting of meteorites. By recalculation, we find that the total of 549 falls in a 100-year period corresponds to a frequency of 0.08 falls per year per $10^6 \text{ km}^2$ inhabited surface.

This is, however, a minimum estimate since we know of provinces with far better yields of meteorites. From the World Maps (Buchwald 1968a) it may be readily seen, e.g., that Western Europe, North India and Japan have contributed relatively many more meteorite falls than, e.g., North Europe, South India and Australia. Common factors in countries with a high rate of reported meteorite falls are a high population density and a good education and information level. China makes a surprisingly low figure in the statistics: in spite of a large area and population, only a total of ten meteorites have been reported and examined. Some other factors, such as superstition or entire lack of interest, seems to play a role in connection with meteorite recovery. But China has, of course, remained an enigma to the West in other respects also.

We will choose three widely separated regions for a closer study.

1. A selected, densely populated area of $10^6 \text{ km}^2$ in North India, comprising essentially the Indus and Ganges plains, has in the period 1861-1940 yielded 41 falls: Butaura 1861, Manbhoom 1863, Gopalpur 1865, Supuhee 1865, Pokhra 1866, Khetri 1867, Moti-ka-nagla 1868, Dyulpur 1872, Nagaria 1875, Bhagur 1877, Dandapur...
1878, Haraiya 1878, Andhara 1880, Pirgunje 1882, Chandpur 1885, Bherai 1893, Ambapar Nagla 1895, Bishunpur 1895, Delhi 1897, Gambat 1897, Sindhi 1901, Bholgati 1905, Karki 1905, Vishnupur 1906, Chainpur 1907, Kohar 1910, Mirzapur 1910, Visuni 1915, Ekh Khera 1916, Rampurhat 1916, Sultanpur 1916, Garhi Yasin 1917, Ranchapur 1917, Atarra 1920, Merua 1920, Haripura 1921, Shikarpur 1921, Jahl deh Kot Lal 1926, Khanpur 1932, Bahjoi 1934, and Ramnagar 1940. This corresponds to 0.51 falls per year per $10^6 \text{ km}^2$. Of the recorded falls, only two were iron meteorites, Garhi Yasin and Bahjoi. We could extend the statistics over a longer period of time, both before 1860 and after 1940. It appears, however, that the reporting of meteorites was particularly good under the British government; and since we are presently searching for the highest reported frequencies, in India, we will limit ourselves to the period 1861-1940.

2. Japan has between 1827 and 1964 yielded the following 18 meteorites: Yonozu 1837, Kesen 1850, Sone 1866, Otomi 1867, Takeouchi 1880, Fukutomi 1882, Kyushu 1886, Higashi-Koen 1897, Nio 1897, Okano 1904, Kijima 1906, Gifu 1909, Tomita 1916, Tone 1918, Kushiike 1920, Numakai 1925, Kasamatsu 1938, and Okabe 1958. Of these, one was an iron meteorite; Okano. Averaged over Japan’s 368,000 km$^2$ we find 0.36 falls per year per $10^6 \text{ km}^2$.

3. Finally, we will examine a small area of 75,000 km$^2$, covering the densely populated Po Valley and part of the adjoining Alpine and Apennine Mountains. There were 12 falls between 1750 and 1970: Albareto 1766, Borgo San Donino 1808, Renazzo 1824, Cereseto 1840, Trenzano 1856, Alessandria 1860, Motta di Conti 1868, Alfianello 1883, Valdinizza 1903, Avče 1908, Vigarano 1910, and Piancaldi 1968. Of these, one was an iron meteorite, Avče. On the average we then have for Northern Italy 0.72 falls per year per $10^6 \text{ km}^2$. But are we at all allowed to make statistical deductions from such heterogeneous series of data? Note that no falls were recorded between 1910 and 1968.

From the available material it is thus probably hazardous to try to wrest more information. We have, however, learned the same lesson as particularly good under the British government; and since we are presently searching for the highest reported frequencies, in India, we will limit ourselves to the period 1861-1940.

2. Japan has between 1827 and 1964 yielded the following 18 meteorites: Yonozu 1837, Kesen 1850, Sone 1866, Otomi 1867, Takeouchi 1880, Fukutomi 1882, Kyushu 1886, Higashi-Koen 1897, Nio 1897, Okano 1904, Kijima 1906, Gifu 1909, Tomita 1916, Tone 1918, Kushiike 1920, Numakai 1925, Kasamatsu 1938, and Okabe 1958. Of these, one was an iron meteorite; Okano. Averaged over Japan’s 368,000 km$^2$ we find 0.36 falls per year per $10^6 \text{ km}^2$.

Finally, we will examine a small area of

<table>
<thead>
<tr>
<th>Table 21. The Smallest Iron Meteorites</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Class</strong></td>
</tr>
<tr>
<td>-----------</td>
</tr>
<tr>
<td>Wedderburn</td>
</tr>
<tr>
<td>Freda</td>
</tr>
<tr>
<td>Dehesa</td>
</tr>
<tr>
<td>Füllinge</td>
</tr>
<tr>
<td>Linville</td>
</tr>
<tr>
<td>Gay Gulch</td>
</tr>
<tr>
<td>Kofa</td>
</tr>
<tr>
<td>Britstown</td>
</tr>
<tr>
<td>Washena</td>
</tr>
<tr>
<td>York</td>
</tr>
<tr>
<td>Maldyak</td>
</tr>
<tr>
<td>Mount Ouray</td>
</tr>
<tr>
<td>Neptune Mts.</td>
</tr>
<tr>
<td>Anoka</td>
</tr>
<tr>
<td>Avče</td>
</tr>
<tr>
<td>Joel’s Iron</td>
</tr>
</tbody>
</table>
day, the total number of falls per year should be corrected upwards a factor of 24/16 = 1.5, yielding a total of about 550 falls per year.

Of the 365 or 550 yearly falls, those falling over Oceans and uninhabited regions are, of course, immediately lost; i.e., we are left with only 14% of the potential meteorite sources, or a total of 50 (75). Of these only 5.5 on the average are brought to the attention of scientists, a rather discouraging result.

For comparison, it is interesting to note the results of the automated Prairie Network, discussed page 17. This has so far, in seven years of operation, recovered only one meteorite (Figures 1a, 1b), much less than originally anticipated (McCrosky & Ceplecha 1969). If we assume that the Network has effectively covered $10^6$ km$^2$, eight night hours on the average, we get a fall frequency of 0.43 per year per $10^6$ km$^2$. This is the roughest approximation of all with statistics based on only one recovered fall. However, the result appears to lie close to the values found above from statistics based upon falls through one or two centuries over widely separated regions. We are probably allowed to conclude cautiously that the frequency of meteorite falls within the last 200 years has largely been constant over the Earth, and that, to a rough approximation, we may expect one fall per day somewhere on the Earth.

For information of the size of falls and finds the reader is referred to page 27 and to Tables 20 and 21 which are self-explanatory.

On the Use of Meteoritic Iron by Our Ancestors

It is quite interesting to note that only a few iron meteorites are known from the Old World, while they are common in North America, Mexico, Chile, South Africa and Australia. See, for example, the World Map, published by Buchwald (1968a). The reason is not difficult to find. The countries of the Old World which have for countless generations been tilled and exploited, have already yielded the majority of the meteorites accumulated through the ages. The iron meteorites have no doubt been utilized by prehistoric man in Europe, either by chipping and cold hammering, by forging or by remelting, and most of this activity has gone unrecorded. An example of the fate of an iron meteorite is revealed by the story of Hraschina in 1751, where one of the two recorded fragments was entirely lost soon after the fall because of the activity of.

Figure 21A. Map of Africa south of 15° S showing all known meteorites: 23 stones, 22 irons and two stony irons. The number of recovered meteorites is proportional to the population density, the educational level and the intensity of farming.
Figure 22. A medieval (?) adze blade (535 grams) exhibiting damascene pattern on the polished and etched surface. Microprobe examination indicates that the adze was produced by forging alternating layers of mild steel and meteoritic, probably hexahedritic, material. The adze was excavated in Central Sweden and is in private possession. Scale bar approximately 3 cm.

Figure 23. Examples of worked iron meteorites of known origin. A forged plate of Lenarto, a coldhammered wedge of Bacubirito, a forged finger ring of Gibeon, and a triangular slab of Toluca with the initials AB, probably those of Aristides Brezina. The specimens are now in the Vienna Museum. Scale bar in centimeters.

Figure 24. Artificially reheated structure of a near-surface section of the Tucson (Carleton) meteorite, U.S.N.M. no. 757. Decomposed limonitic products (gray), with metal particles (white), and brecciated silicates (black). Polished, unetched. Scale bar 50 μ.

Figure 25. Artificially reheated structure of Ssyromolotovo (Chicago no. 1148). The limonite in a corroded crack has partially decomposed into a lacework pattern, and tiny metallic particles have precipitated within the limonite. Polished, unetched. Scale bar 10 μ.

is, thus, superfluous since the class is very heterogeneous and mainly based upon the erroneous interpretation of damaged hexahedrites (e.g., Chesterville, Cincinnati, Locust Grove and San Francisco del Mezquital) and coarse octahedrites (e.g., Campo del Cielo).

The 94 reheated meteorites constitute no less than 18% of all iron meteorites. This is a surprisingly large percentage and indicates the eagerness and curiosity with which our forefathers utilized the costly material. However, it is not generally accepted that the percentage is so high. Perry (1944: 71), an authority on iron meteorites, thus stated after a thorough examination of many meteorites: "We may fairly conclude that artificial metabolites, though perhaps sometimes produced, are rare."

Often, only a fragment of the whole mass has been reheated. In other cases, one or two masses of a shower have been maltreated, while the remainder has escaped. It is blacksmiths. Elbogen was apparently exposed to the fire of a medieval blast furnace, but miraculously survived, while Bitburg, Magura and Netschaevero were almost entirely lost.

In Appendix 5, 94 iron meteorites which have been exposed to artificial reheating and working are listed. It is important to note that such reheating may have taken place (Buchwald 1965a; 1968d). Particularly when estimating the effect of cratering impact and of collisional shocks in general, it is necessary to bear in mind that man’s curiosity has often led him to reheat the meteorites, without leaving any record of this experiment for future generations. Since the structures which are produced by artificial reheating are deceptively similar to some genuine structures from shock reheating, one has to be extremely careful. Sometimes the artificial reheating effectively destroyed the original cosmic structures, causing great confusion. The classifying term "nickel-poor ataxite" which has been used for generations (Cohen 1903d: 1; Hey 1966: xix)
unusual for museum labels to state that a particular sample has been artificially reheated, so one normally has to detect the damage oneself. In my experience, the damage is best revealed on a near-surface section with corrosion products. The sample is initially examined in the polished state, and the interfaces between the corrosion products and the meteoritic minerals are closely studied. Even brief reheatings above 550-600°C will alter the limonitic products; usually tiny ~1 μ metallic particles will precipitate in them, and the kamacite-limonite interfaces will acquire a lace-like structure. At 800°C and above, oxidation will create an intercrystalline attack along the austenite grain boundaries. At 900°C and above, the sulfides will react with oxygen and form low-melting quaternary eutectics, such as Fe-Ni-S-O. At 1000°C and above, the phosphides will melt.

On the etched sections, additional information is to be gained. The kamacite matrix will, if heated above 750°C, transform to fine-grained austenite, which upon cooling will transform to the serrated, unequilibrated α₂. This structure is, in principle, similar to the heat-affected rim zone from atmospheric flight and may be confused with it. However, proper evaluation of the other components of the structure, the thermal gradient and the depth below the surface will usually allow one to distinguish between the two kinds.

Parallel ghost-lines indicate unidirectional forging and insufficient homogenization, seen in, e.g., samples of

Figure 26. Artificially reheated structure of Yahnuitlan (Tempe no. 129a). Recrystallization and daubreelite exsolution in troilite nodule at 700-800°C. Polished; crossed polars. Scale bar 80 μ.

Figure 27A. Artificially reheated structure of Burlington (U.S.N.M. no. 978). Above original kamacite lamella, below original taenite lamella. Both are transformed to unequilibrated α₂ structures due to reheating around 1000°C. Polished, etched. Scale bar 100 μ.

Figure 27B. Artificially reheated sample of Odessa. This particular slice was heated in air to 850°C for 60 minutes, then air cooled. Below an exterior layer of hexagonal hematite, Fe₂O₃ (H), follows cubic magnetite, Fe₃O₄ (M). The next layer, which at 850°C was wüstite, FeO, decomposed partially on cooling to magnetite (W+M). The magnetite precipitated as skeleton crystals in grain interiors and as rims along interfaces and grain boundaries. Between the wüstite layer and the unoxidized meteorite there is a transitional layer (T) with fine metallic particles. Except for layers H and T, the zones resemble those of fresh, uncorroded falls. Etched. Crossed polars. Scale bar 20 μ.

Figure 28. Artificially reheated structure of Toubil River (Moscow no. 2485). Reheating to about 1000°C has melted the schreibersite and caused fine-grained eutectics (spotted vein across the section). The kamacite has been transformed to α₂, but the reheating was insufficient to dissolve the precipitates along the Neumann bands. Etched. Scale bar 80 μ.
Figure 29. Artificially reheated structure of Rodeo (Tempe no. 101ax). A central schreibersite vein with 2-10 μ wide, diffuse reaction zones against kamacite, and with spheroidized limonitic inclusions. The kamacite has been transformed to α₂. Estimated peak temperature 800-900°C. Etched. Scale bar 30 μ.

Campo del Cielo, Prambanan, Babb’s Mill (Troost’s Iron) and Cacaria. Recovery —i.e., unexpectedly low hardnesses — and incipient recrystallization indicate the mildest damage, from heating to 400-750°C, and these effects, taken alone, are difficult to attribute definitely to artificial reheating. Again, however, if other features are considered, particularly the corrosion products and the exterior shape and damage, it is usually possible to arrive at a conclusion as to the cause of the anomalous structures and mechanical properties.

Finally, cold-worked meteorites are very common; the damage is normally superficial and adjacent to flat hammerred, chiseled and torn surfaces. In several cases it is, however, difficult to distinguish between artificial damage and the deformation that occurred in the atmosphere when — or if — the meteorite fragmented and produced a shower.

Figure 30. In a laboratory experiment, a small corroded Odessa sample was reheated in the air to 850°C for 60 minutes. The limonite partially decomposed, segregating fine metal globules (white), and the interfaces with kamacite (above) and taenite (below) were altered to lacework structures. The effect was already visible but not very pronounced after 10 minutes at 650°C. Polished. Oil immersion. Scale bar 20 μ.

It is often maintained that distorted Widmanstätten lamellae and other signs of local cold-work are caused by the meteoritic impact with the ground. I have only been able to detect few significant examples of this postulated damage. If cold-work is present it is usually (i) of preterrestrial cosmic origin, (ii) caused by the fragmentation in the atmosphere or (iii) caused by artificial working. In some cases, when large meteorites impacted with high velocities, e.g., Sikhote-Alin, the broken and fragmented masses may be found quite close together in the impact holes, suggesting that the final fragmentation and superficial cold-deformation occurred at the time of impact. This impact deformation is, however, the exception rather than the rule.