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The Chemical Classification of Iron Meteorites—V Groups IIIC and IIID and other Irons with Germanium Concentrations between 1 and 25 ppm

JOHN T. WASSON AND RUDOLF SCHAUDY

Department of Chemistry and Institute of Geophysics and Planetary Physics, University of California, Los Angeles, California 90024

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Concentrations of Ni, Ga, Ge, and Ir are reported for iron meteorites belonging to two small but definite chemical groups, and other irons with Ge contents between 1 and 25 ppm. The new groups are characterized as follows:

Group	Structure	Ni (%)	Ga (ppm)	Ge (ppm)	Ir (ppm)
IIIC	Off-Of	11–13	11–26	8–35	0.07–0.55
IIID	Off-D	16–23	1.5–5.2	1.4–4.0	0.02–0.07

These groups may be related to each other. Most other meteorites in this Ge concentration range are found to be unique in their chemical composition. One cluster of three irons (Gay Gulch, Garden Head, and Kofa) and two of two (Santa Catharina and Twin City, Cambria and Soroti) may be genetically related.

Introduction

This is the fifth of a series of papers reporting the results of a study of the concentrations of Ni, Ga, Ge, and Ir in the iron meteorites and the metal phases of the stony-iron meteorites. The previous reports (Wasson, 1967; Wasson and Kimberlin, 1967; Wasson, 1969; Wasson, 1970*a*) dealt with irons of all four Ga–Ge groups as described by Lovering *et al.* (1957). As a result of improved chemical data and the large number of meteorites analyzed, nine resolved chemical groups have previously been defined. In this paper we shall discuss two new, small groups and other iron meteorites with Ge contents between 1 and 25 ppm. Included are all irons in this compositional range from a total of about 460 iron meteorites analyzed in this laboratory.

Experimental

The procedure for Ni, Ga, and Ge has been reported by Wasson and Kimberlin (1966, 1967). No important changes have been made since that time. Ni is determined on an aliquot of the dissolved sample by atomic absorption analysis. The 95% confidence limits on the means of duplicate determinations are about ±2% for Ni and ±4% for Ga and Ge. Ir is determined by a neutron-activation procedure described in Kimberlin *et al.* (1968). In this case the 95% confidence limits on the means of two determinations extend about ±10% about the means.

The general agreement between our results and those of other authors is quite good. A detailed comparison of Ni, Ga, and Ge values was given by Wasson and Kimberlin (1967), and a comparison of Ir values by Kimberlin *et al.* (1968).

Samples

The meteorites are listed alphabetically in Table I. With one exception, each specimen was polished and etched, and the structure observed under a microscope. Our estimated kamacite bandwidths are presented in column 4 of Table I. The Buchwald structural class symbols (see Wasson, 1970*a*) are shown in column 3 of Table I. In columns 5 and 6 are listed the

TABLE I

Ni, Ga, Ge and Ir Concentrations in 27 Iron Meteorites and the Metal of a Pallasite[a]

Meteorite	Chemical group	Structural class	Bandwidth/ (mm)	Source[c]	Catalog number	Ni (%) mean	Ga (ppm) mean	Ge (ppm) Replicates	Ge (ppm) Mean	Ir (ppm) Replicates	Ir (ppm) Mean
Anoka	IIIC	Off	0.15	MPIM	97/1	11.95	17.2	15.3, 15.1[d]	15.7	0.15, 0.17	0.16
Cambria	Anom	Of	0.26	AmhC	—	10.17	11.1	1.43[d]	1.52	0.85, 0.91, 1.79[e]	0.88
Carlton	IIIC	Off	0.16	UCLA	117	13.0 ± 0.3	11.4	8.25, 8.64[d]	8.59	0.086, 0.50, 0.080	0.076 ± 0.010
Cowra	Anom	Opl-D	0.035	AM	DR6444	12.94	73.5	12.6, 12.1[d]	12.3	19.7, 8.9, 13.5	14.0 ± 5.0
Dayton	IIID	Off	0.028	SI	1506	17.02	5.16	3.59, 3.51[d]	3.52	0.031, 0.025	0.028
Edmonton, Ky.	IIIC	Off-Of	0.20	SI	1413	12.7 ± 0.3	25.4	—[d]	34.6	0.55	0.55 ± 0.11
El Qoseir	Anom	D	—	KMAN	650	13.19	6.15	11.5, 11.9	11.7	5.4, 5.6	5.5
Föllinge	IIID	Off	0.035	NRS	—	18.13	4.02	3.15, 3.15	3.15	0.074, 0.069	0.072
Freda	IIID	D	—	SI	1342	22.57	2.09	2.25, 2.23	2.24	0.030, 0.012	0.021 ± 0.009
Garden Head	Anom	Opl	0.035	GSC	0707301	16.96	10.7	16.0, 17.2	16.6	0.12, 0.12	0.12
Gay Gulch	Anom	Opl	0.06	GSC	0701302	15.06	6.68	10.6, 10.7	10.7	0.10, 0.11	0.11
Glorieta Mountain	Pallas	Of-Pal	0.25	UCLA	182	12.04	13.2	9.9[d]	10.7	0.021, 0.009	0.014 ± 0.007
Grand Rapids	Anom	Of	0.40	UCLA	186	9.26	17.9	13.1[d]	13.7	16, 13	14
Havana	IIIC	Off	0.16	ISM	—	11.37	20.5	21.4, 21.7	21.6	0.58, 0.10	0.3 ± 0.2
Illinois Gulch	Anom	D	—	FMNH	Me839	11.68	2.80	2.63, 2.90	2.76	5.9, 4.6	5.3 ± 0.6
Kofa	Anom	Opl-D	0.016	FMNH	Me1993	18.27	4.79	8.70, 8.52	8.61	0.11, 0.09	0.098
La Caille	Anom	Om	1.1	HarU	6	9.11	13.7	21.0, 22.0	21.5	9.6, 9.9	9.7
Laurens County	Anom	Off	0.15	NMW	D2186	12.95	10.5	22.9, 21.9	22.4	9.7, 6.0	7.9 ± 1.8
Mount Magnet	Anom	D-Opl	0.015	WAM	12375e	14.56	7.53	5.36, 5.08[d]	5.26	0.014, 0.011	0.012
Mungindi	IIIC	Off-Of	0.20	AM	3669	11.5 ± 0.4	19.4	22.2[d]	22.1	0.48, 0.43, 0.50	0.47

Piñon	Anom	D	—	SI	861	15.54	2.32	1.16, 1.08[d]	1.15	14, 16	15
Santa Catharina	Anom	D	—	HarU	360	33.62	5.28	8.97, 8.19[d,e]	9.07	0.029, 0.011	0.020 ± 0.009
Soper	Anom	Anom	—	SI	1312	5.70	9.71	16.0[e] 10.7, 10.8	10.8	0.009, 0.013, 0.13[e]	0.011
Soroti	Anom	Off	0.12	SI	1516	12.88	14.1	4.89, 5.54	5.22	0.047, 0.074	0.060 ± 0.015
Tazewell	IIID	Off	0.035	UCLA	361	16.64	4.69	3.67, 3.47[d]	3.79	0.075, 0.051	0.063 ± 0.013
Twin City	Anom	D	—	SI	1770	30.06	4.54	6.83, 7.77, 7.86, 7.19	7.42	0.010, 0.019, 0.016	0.015 ± 0.003
Washington County	Anom	Anom	—	HarU	569	9.96	15.5	19.7, 21.3	20.5	0.062, 0.072	0.067
Wedderburn	IIID	D	—	GSV	—	22.36	1.51	1.40, 1.60[d]	1.47	0.037, 0.068	0.052 ± 0.016

[a] The list includes all known irons with Ge concentrations between 1 and 25 ppm, and Edmonton, Ky., with 35 ppm Ge.

[b] Bandwidth means are believed accurate to ±20%.

[c] Source names: AM, Australian Museum; AmhC, Amherst College; KMAN, Committee on Meteorites, Academy of Sciences, USSR; GSC, Geological Survey of Canada; FMNH, Field Museum of Natural History; GSV, Geological Survey of Victoria; HarU, Harvard University, ISM, Illinois State Museum; MPIM, Max-Planck Institut, Mainz; NMW, Naturhistorisches Museum, Vienna; NRS, Naturhistoriska Riksmuseet, Stockholm; SI, National Museum of Natural History, Smithsonian Institution; UCLA, University of California, Los Angeles; WAM, Western Australian Museum.

[d] For previously published replicate values see Wasson (1967), and Wasson and Kimberlin (1967).

[e] Values not included in the means.

source and catalog numbers of the analyzed samples.

The typical size of the irradiated samples was about 1 g. Large inclusions were avoided. Sampling variations were found to be small although these were generally the major contribution to the errors. Samples were cleaned before, and etched before and after the irradiation.

In columns 7–12 of Table I are listed mean Ni, mean Ga, replicate and mean Ge, and replicate and mean Ir concentrations of 28 iron meteorites, including eight for which Ga and Ge values were published in Wasson (1967). and five which are repeated from Wasson and Kimberlin (1967). Some of these results have undergone slight revisions due to additional determinations.

Classification

Wasson and Kimberlin (1967) proposed that genetic groups of iron meteorites were characterized by (1) limited concentration ranges of all elements compared to the range found in the iron meteorites as a whole; (2) smooth variations in the concentration of one element plotted against that of another; (3) similar structures. These rules have been applied to define two new groups of irons having Ge concentration ranges of 8–35 ppm and 1–4 ppm. These are illustrated in Fig. 1, which shows Ge contents in the range 1–50 ppm plotted against Ga and against Ni concentrations, and in Fig. 2, in which Ir is plotted against Ni concentration. The ten meteorites belonging to groups IIIC and IIID are listed in Table II in decreasing Ge order. A description of their structures is given later. On the Ge versus Ga plot there seems to be a third suite of at least eight related irons, which plot in a narrow band to the left IIIC and IIID. However, a glance at the Ge–Ni part of this plot and at the Ir–Ni diagram shows that these objects fail to form coherent groups. They will be discussed further later. Figure 1 also shows the positions of the groups IIIA and IIIB for comparison.

Following the arbitrary designation of the Lovering *et al.* (1957) groups—I through IV from high to low Ga and Ge content—and our designation of the resolved groups

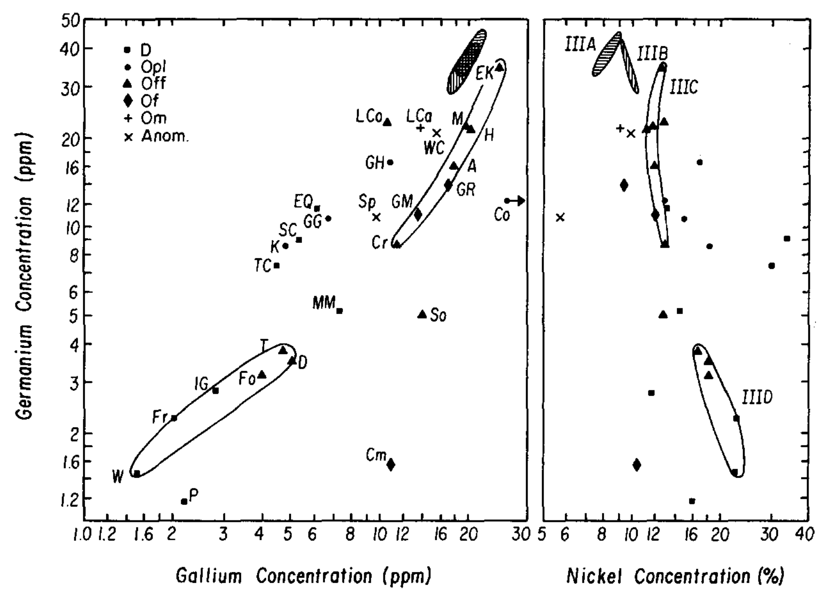


Fig. 1. Plots of Ge vs. Ga and Ge vs. Ni for iron meteorites with Ge concentrations between 1 and 25 ppm, and Edmonton, Ky., with 35 ppm Ge. The new groups IIIC and IIID are defined as those meteorites falling within the designated fields on both plots. The plots are extended to 50 ppm in order to show the locations of the previously defined groups IIIA and IIIB.

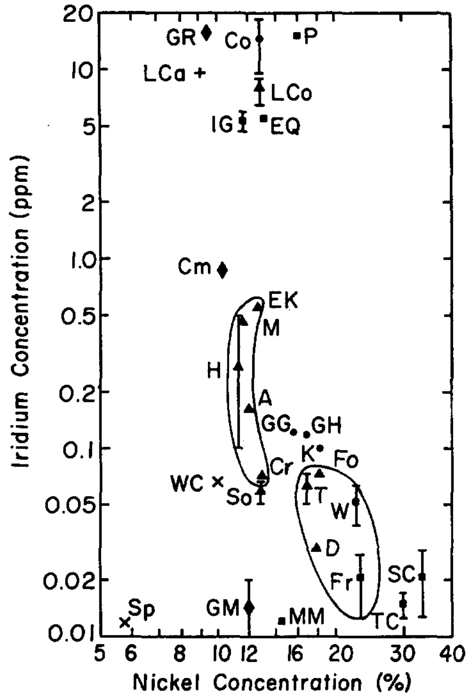


FIG. 2. Plot of Ir vs. Ni for iron meteorites discussed in this paper. Although groups IIIC and IIID may be different portions of a single sequence, the apparent discontinuity in slope accompanying the hiatus between the groups lends some uncertainty to such a proposal. Symbols have same meaning as in Fig. 1.

—the high Ge group in the general range of Lovering's groups is given the letter A, the next lower a B, etc.—the two new groups are called IIIC and IIID. Although this designation is not entirely satisfactory, we plan to continue its use to avoid unnecessary confusion. Of the original nine groups, only IIIA and IIIB, and IIA and IIB seem to be genetically related to one another. All others appear to be independent.

Group IIIC

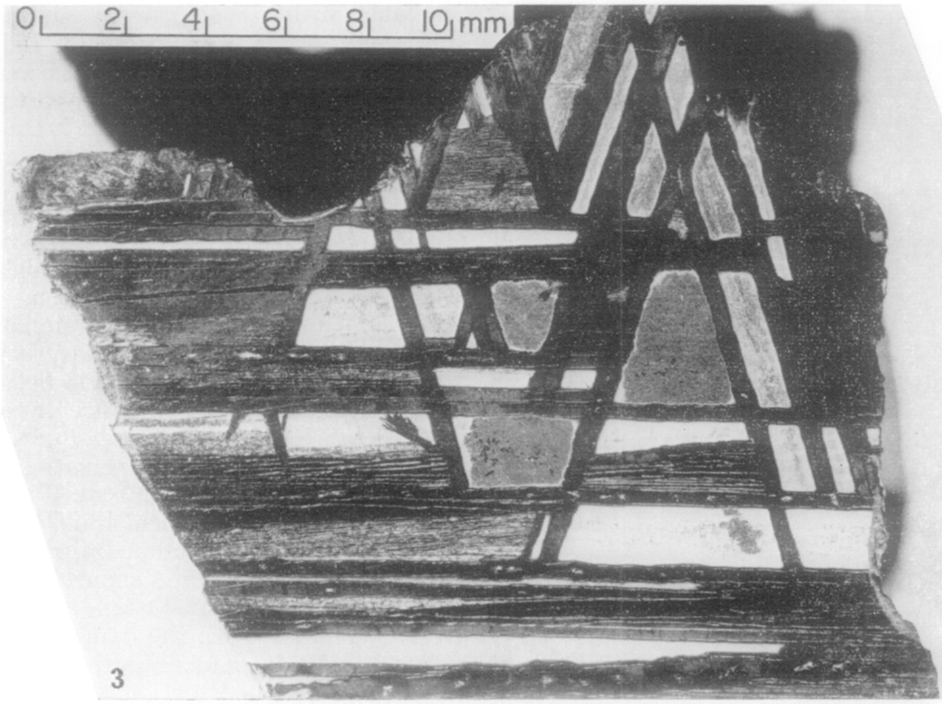
The possible existence of a group IIIC was suggested by Wasson and Kimberlin (1967) when they observed that the meteorites Edmonton (Kentucky), Mungindi, Anoka, and Carlton showed smooth curves on the Ge versus Ga and Ge versus Ni plots. At that time no reliable Ir values were available for these meteorites. In the meantime, replicate determinations for Ir have been carried out, and a fifth iron (Havana) was found, which is closely related to the first four irons. As shown in Fig. 2, the five meteorites plot in a quite narrow range on the Ir–Ni diagram. Within the group, the Ni concentration is highest in Carlton (13.0%), goes down to 11.4% in Havana, and then increases slightly in the high Ge members Mungindi and Edmonton.

All five meteorites are very similar in structure. The kamacite bands are long and the mean bandwidths fall between 0.15 and 0.25 mm; these irons are therefore finest octahedrites (Off), according to the Buchwald classification (private communication: see Wasson, 1970*a*). With the exception of Havana, which is a bead from a necklace found in an Indian burial mound (and therefore somewhat deformed), the Widmanstätten structures are very regular, with the kamacite often as much as 3 cm long. Figure 3 shows a polished and etched section of Mungindi, a typical member of this group. Some of the kamacite lamellae of Carlton and most bands of our Anoka sample are slightly swollen, reflecting the occurrence of schreibersite in these bands.

Group IIID

This small group consists of five meteorites: Tazewell, Dayton, Föllinge, Freda, and Wedderburn. All of these irons are characterized by high Ni contents (between 16.6 and 22.6% Ni). The Ga/Ge ratio is approximately 1, the absolute values of these two elements fall between 1.4 and 5.2 ppm. The Ir contents are consistently low (in a range from 0.02 to 0.07 ppm).

The possibility of a genetic relationship between Föllinge, Tazewell, and Dayton was suggested to us by Buchwald (1967*a*, *b*, private communication, 1968). Both Föllinge and Tazewell are finest octahedrites containing 20–50 μ wide α-lamellae in a martensitic matrix. The detailed structure of Föllinge is discussed by Buchwald (1967*a*, *b*). Figure 4 shows two portions of a section of Tazewell, which is similar to Föllinge. Dayton shows a still



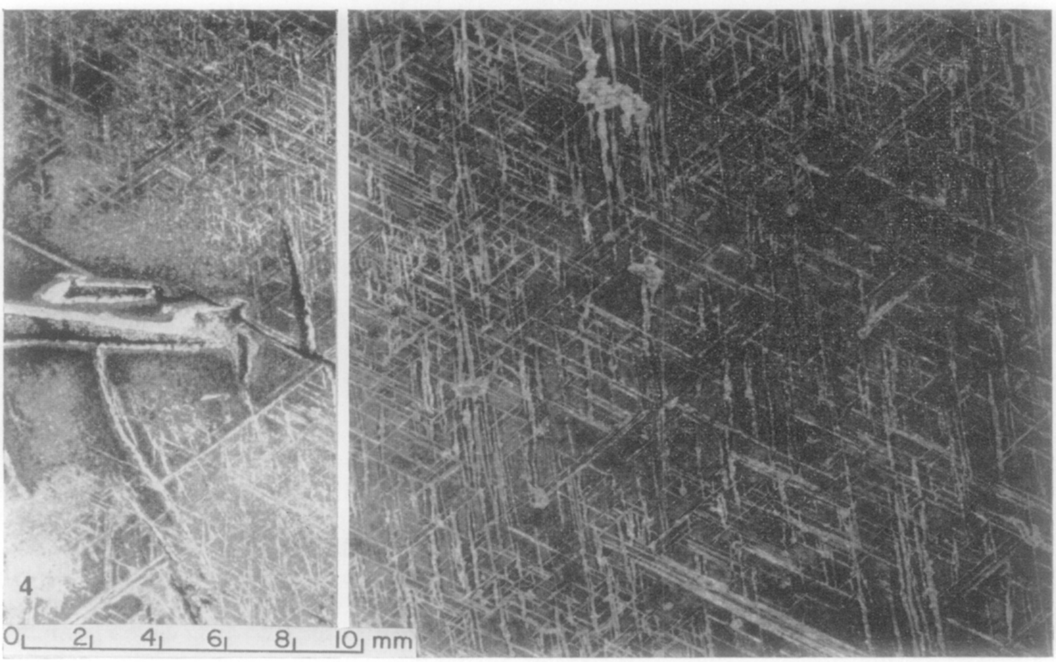


FIG. 3. A polished and etched section of a small slab of Mungindi, a typical representative of group IIIC. The mean bandwidth within this slab is about 0.2 mm. Small schreibersite inclusions are seen in most of the larger kamacite bands. Photo by J. Kimberlin.

FIG. 4. Two portions of a polished and etched section of the low-Ni group-IIID member, Tazewell. The structure is quite regular, as shown on the right, except near large schreibersite inclusions, as shown on the left. The mean kamacite bandwidth is about 0.035 mm in Tazewell. Cooling rates estimated from kamacite bandwidths and Ni concentrations are about the same in Mungindi (Fig. 3) and Tazewell. Photo by J. D. Kun.

finer Widmanstätten pattern; the kamacite bands are only 15–40 μ wide. One part of the etched surface of our sample is characterized by rows of aligned parallel bands of kamacite, the other part consists of a very fine and compact network of kamacite lamellae.

Freda and Wedderburn differ in their structures from the other three irons as a result of their higher Ni contents, which are 22.6 and 22.4%, respectively. Both meteorites contain kamacite crystals in the form of rectangles, trapezoids, and needles, set in a matrix of fine, dark plessite. In the case of Wedderburn they form approximately 15% of the etched area. The dimensions of these kamacite crystals are typically about 0.1 × 0.2 mm, with small inclusions of schreibersite in their interiors. In Freda the kamacite crystals are smaller and very irregular in shape, and also contain small schreibersite inclusions. The kamacite portion is less than 10% of the etched area.

On the basis of our Ni, Ga, and Ge determinations we cannot rule out the possibility that groups IIIC and IIID are related to each other, although such a combined group would show a widely extended range of Ga and Ge concentrations. A similarly wide concentration range was found earlier in group I (Wasson, 1970*a*). As can be seen in Fig. 1, the two groups form a single smooth curve; however, a discontinuity seems to be present on the Ni–Ir plot.

The differences in structure between the two groups are best considered in terms of cooling rates, i.e., the combination of bandwidth and Ni concentration. Goldstein and Short (1967) have estimated cooling rates of 193 iron meteorites, among them four members of group IIIC and three of group IIID. They find cooling rates between 1 and 3°C per megayear (My). We have reestimated the cooling rates using our bandwidths and revised Ni concentrations, and present the results in Table II. Our cooling rates tend to be slightly higher than those of Goldstein and Short, but are the same within the error inherent in the estimation. Our values range from 2 to 5°C My^{-1} within each group, the relatively wide range probably reflecting the errors of estimation rather than real variations. The cooling rate data are consistent with groups IIIC and IIID having originated in the same parent body.

TABLE II

COMPOSITIONAL DATA, COOLING RATES, AND COSMIC-RAY AGES OF IRON METEORITES BELONGING TO GROUPS IIIC AND IIID, LISTED IN ORDER OF DECREASING Ge CONCENTRATION

Meteorite	Ni (%)	Ga (ppm)	Ge (ppm)	Ir (ppm)	Cooling rate (°C My^{-1})	Cosmic-ray ages (My)
Group IIIC						
Edmonton, Ky.	12.7	25.4	34.6	0.55	2	—
Mungindi	11.5	19.4	22.1	0.47	4	820 ± 100
Havana	11.37	20.5	21.6	0.3	5	—
Anoka	11.95	17.2	15.7	0.16	5	685 ± 150
Carlton	13.0	11.4	8.59	0.076	2	605 ± 70 625 ± 75
Group IIID						
Tazewell	16.64	4.69	3.79	0.063	4	—
Dayton	17.02	5.16	3.52	0.028	5	215 ± 85
Föllinge	18.13	4.02	3.15	0.072	2	—
Freda	22.57	2.09	2.24	0.021	—	—
Wedderburn	22.36	1.51	1.47	0.052	—	100 ... 200[a]

[a] Estimated from rare-gas data.

TABLE III

CONCENTRATION DATA AND COOLING RATES FOR A TRIPLET AND TWO DOUBLETS OF POSSIBLY RELATED IRON METEORITES

Meteorite	Ni (%)	Ga (ppm)	Ge (ppm)	Ir (ppm)	Cooling rate (°C My^{-1})
Garden Head	16.96	10.7	16.6	0.12	3.5
Gay Gulch	15.06	6.68	10.7	0.11	4
Kofa	18.27	4.79	8.61	0.098	5
Santa Catharina	33.62	5.28	9.07	0.020	—
Twin City	30.06	4.54	7.42	0.015	—
Soroti	12.88	14.1	5.22	0.060	4
Cambria	10.17	11.1	1.52	0.88	5

In contrast to cooling-rate data, the cosmic-ray exposure ages of Voshage (1967), which are based on the K^{41}–K^{40} method, indicate different cosmic histories for the two new groups. As shown in Table III, Voshage found cosmic-ray ages between 600 and 800 My for three members of group IIIC. On the other hand, he gives 215 ± 85 My for the IIID member Dayton, and an estimated age of 100 to 200 My for Wedderburn. Within experimental errors, the data are consistent with a single breakup of the group IIIC parent body about 700 My ago, and a single breakup event at about 200 My which produced the group IIID irons. Thus, if the groups originated in a single parent body, it seems to have been fragmented in at least two separate collisional events.

On the basis of all the summarized data, we believe it somewhat more likely than not that groups IIIC and IIID are separate segments of a single, larger group. We believe, however, that they should be treated as separate groups in tabulating iron meteorite data until the evidence is more conclusive.

Three Clusters of Possibly Related Irons

It is of interest to consider whether a close relationship might exist between any of the remaining irons in the 1–25 ppm Ge concentration range. A triplet of irons with similar properties are Garden Head, Gay Gulch,[1] and Kofa. Compositional and cooling-rate data are listed in Table III. The gross structures of Garden Head and Gay Gulch are those of very similar plessitic octahedrites, whereas the high-Ni iron Kofa has very few obviously-oriented kamacite spindles. Nonetheless, if one estimates the bandwidths of these few schreibersite-free kamacite spindles in Kofa, and the more plentiful ones in Gay Gulch and Garden Head, and combines these with Ni concentrations to estimate cooling rates by the Short–Goldstein (1967) method, one finds values between 3.5 and 5°C My^{-1}, which are consistent with all objects having cooled at this same rate. We think it is likely that these three irons are genetically related.

Santa Catharina and Twin City comprise a pair of closely related irons. The compositional evidence is summarized in Table III, and shows that Ni is about 10% lower, and Ga and Ge about 20% lower in Twin City than in Santa Catharina, well

[1] We are indebted to J. A. V. Douglas (private communication, 1968) for calling to our attention (1) that Garden Head and Gay Gulch have very similar structures, and might be related; and (2) that Gay Gulch and Skookum (a group IVB iron listed as Klondike in Wasson, 1967) are incorrectly paired in Hey (1966) under the name Klondike. We have followed the nomenclature proposed by Douglas for these irons, and agree with him that use of the name Klondike should be ceased to avoid further confusion.

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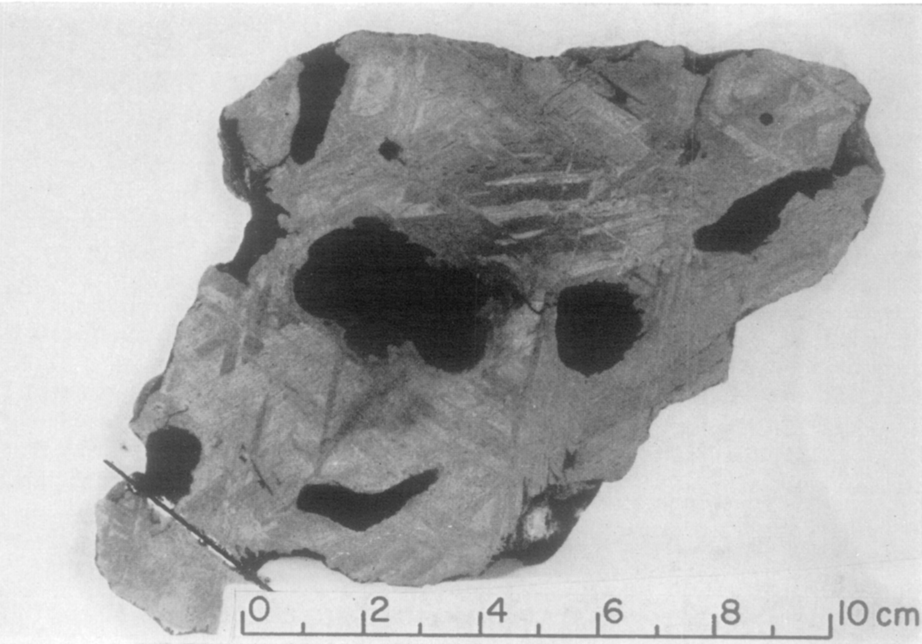

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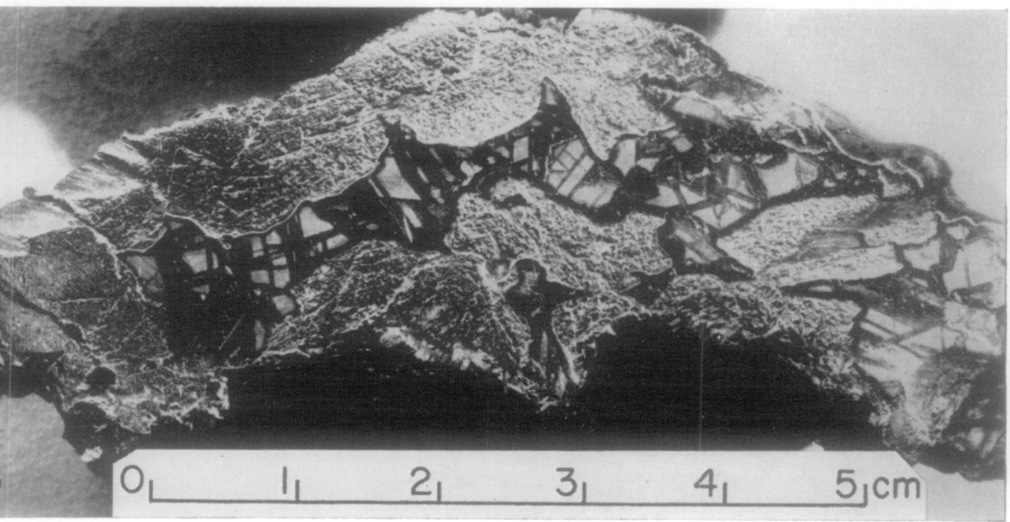

FIG. 5. Polished and etched section of Cambria from Amherst University collection. The large dark areas are troilite nodules, which are surrounded by a thin layer of schreibersite. If this section of Cambria is representative, its troilite content is about 15–20%, which is one of the highest values known. The dark line in the lower left marks the position where our sample was removed. Photo by R. D. Fink.

FIG. 6. A polished and etched section of the Soroti meteorite. This unique meteorite contains about 60 vol.% troilite, and 40% metal. No other meteorite has a comparable content of troilite. Soroti and Cambria may be related—see text for details. Photo courtesy of Smithsonian Institution.

within the ranges normally encountered in resolved chemical groups of iron meteorites. The Ir contents are the same within experimental error.

Two other irons, Cambria and Soroti, contain unusually large amounts of troilite. Photos of these irons are shown as Figs. 5 and 6. About 14% of the Cambria section is troilite. Silliman (1845) notes that the original weathered mass had many holes where troilite nodules had fallen out. Thus, it seems reasonable that the true sulfide content of Cambria is higher—perhaps about 20 vol.%. The Soroti iron, an observed fall, was carefully described by Henderson and Perry (1958). On the basis of the density observed for specimens weighing 170 and 190 g, they calculated that the meteorite consisted of about 60 vol.% troilite. This estimate is also likely to be low, since there was some evidence that ablation and handling had preferentially eroded troilite, although it had not removed entire nodules, as in Cambria. The abundance of troilite relative to metal would appear to be about six times greater in Soroti than in Cambria: thus the two irons cannot be very closely related. The concentration data tabulated in Table III gives much the same impression. The Ir concentration in Cambria is about 15 times greater than that in Soroti. However, this range is slightly less than that found between extreme members of groups IIIA or IIA, and, as in all chemical groups for which a Ni–Ir correlation is observed, Ir varies inversely with Ni. The Ga/Ge ratio decreases from about 7 in Cambria to about 3 in Soroti. Although such a large change has not been observed in any other chemical group, this ratio always tends to increase with increasing Ge concentration within resolved groups. We think it is slightly more likely than not that Cambria and Soroti are genetically linked. It is of interest to point out that the only other high-troilite iron known to us is the Waterville iron. According to the low-resolution photo shown in Nininger and Nininger (1950), this object contains about 20 vol.% troilite, with the nodules considerably smaller than those in Cambria. Waterville contains 196 ppm Ge, and is clearly unrelated to Cambria or Soroti.

Unique Irons with 1–25 ppm Ge

Table IV lists the 11 apparently anomalous irons in the Ge concentration range studied. Since we have no basis for relating any of these objects, we have not attempted to estimate cooling rates.

Laurens County is a very fine octahedrite (Off) with long, regular, kamacite bands, quite similar to the members of group IIIC in texture. However, it plots well to the left of the group IIIC field on the Ga-Ge portion of Fig. 1, and contains much more Ir than do the members of this group. La Caille is a medium octahedrite

TABLE IV

CONCENTRATION DATA FOR 11 ANOMALOUS IRONS (INCLUDING ONE PALLASITE) LISTED IN ORDER OF DECREASING Ge CONCENTRATION

Meteorite	Ni (%)	Ga (ppm)	Ge (ppm)	Ir (ppm)
Laurens County	12.95	10.5	22.4	7.9
La Caille	9.11	13.7	21.5	9.7
Washington County	9.96	15.5	20.5	0.067
Grand Rapids	9.26	17.9	13.7	16
Cowra	12.94	73.5	12.3	14
El Qoseir	13.19	6.15	11.7	5.5
Glorieta Mountain	12.04	13.2	10.7	0.014
Soper	5.70	9.71	10.8	0.011
Mount Magnet	14.56	7.53	5.26	0.012
Illinois Gulch	11.68	2.80	2.76	5.3
Piñon	15.54	2.32	1.15	15

(Om) with a mean kamacite bandwidth of 1.1 mm. Washington County is of special interest because it contains solar-type primordial rare gases (Schaeffer and Fisher, 1959; Signer and Nier, 1962). No other iron closely resembles Washington County in composition. Comerford (1970) called attention to the structural similarity of this object to Juromenha, but the latter contains about 41 ppm Ge and appears to be a reheated high-Ni member of group IIIA.

Grand Rapids is a fine octahedrite (Of) with long, regular kamacite lamellae and a large number of small schreibersite inclusions embedded in the kamacite. The matrix of Cowra is fine plessite containing many small kamacite needles and spindles, typically 0.02–0.05 mm wide and 0.5 mm long, which are clearly oriented about octahedral planes. Its Ga/Ge ratio is extremely high for an iron with a Ge concentration about 1 ppm. El Qoseir shows some structure (fine radiating "flowers"), but no octahedral orientation.

Glorieta Mountain is a fine octahedrite with some pallasitic areas. It has far less Ge than all other pallasites we have studied, the next lowest being Albin, with 29.4 ppm Ge (Wasson and Sedwick, 1969). Buseck and Goldstein (1969) have also shown that Glorieta Mountain shows a greater inhomogeneity in olivine composition than any other pallasite. Although it plots in group IIIC fields on both the Ge–Ga and Ge–Ni plots (Fig. 1), Glorieta Mountain's low Ir content and (according to Buchwald) its structure rule out a close relationship with the other members of this group. Soper is classified as a Ni-poor ataxite. It is one of only three iron meteorites with Ni concentrations between 5 and 6% which are not members of groups IIA or IIB. The others are Zacatecas and Kendall County, which seem to be related to group I (Wasson, 1970*a*, *b*). On the Ge–Ga and Ge–Ni diagrams, Mount Magnet is located in the hiatus between groups IIIC and IIID. If this iron were a member of one of these two groups, its structure should be that of a very fine octahedrite with continuous kamacite bands between 0.05 and 0.2 mm wide. Instead, the structure is that of an ataxite with many kamacite needles or very rudimentary bands (maximum width about 0.02 mm) in a plessitic matrix. This deviation in texture probably indicates a higher cooling rate. Figure 2 shows that it is much lower in Ir content than would be expected if it occupied an intermediate position between groups IIIC and IIID. V. Buchwald (private communication) has confirmed that Mount Magnet is structurally different from the members of groups IIIC and IIID, and notes that it also contains a significant amount of silicates. It will be interesting to see what composition these silicates have. The high Ni content and relatively high apparent cooling rate tend to rule out a close relationship between it and Glorieta Mountain or the other pallasites.

Illinois Gulch was available only as sawings, and thus no structural observations could be carried out. Lastly, Piñon contains numerous irregularly shaped kamacite areas and a few needles in a matrix of fine plessite. The larger kamacite crystals contain schreibersite inclusions.

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