the pinyon-juniper woodland and desert grassland zones of Shantz and Zon, with spruce and fir occupying the existing ponderosa pine zone. There is a serious error in the Shantz and Zon map from which the "full-glacial" map was traced: pinyon-juniper woodland is lacking throughout much of the peninsular salient so mapped in the Big Bend area. Even the Santiago and Dead Horse mountains, which form the axis of the salient, are sparsely vegetated with desert shrubs and grasses, and the very few relict populations of woodland species are narrowly restricted to the highest elevations of the mountains. [For a description of the vegetation of the Dead Horse Mountains, see P. V. Wells, *Southwestern Nat.* **10**, 256 (1965).] Furthermore, the pluvial presence of xerophilous woodland vegetation dominated by two-needled pinyon pine at a relatively high elevation (as evidenced by abundant macrofossils in the full-glacial wood rat midden deposit at Burro Mesa, only 400 m below existing stands of *Pinus ponderosa*) suggests that the magnitude of downward displacement of ponderosa pine "parkland" in the Southwest (as much as 1200 m, as evidenced by high relative percentages of pine pollen, species undetermined, in pluvial sediments) has been overestimated.
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12. R. F. Flint, chairman, *Glacial Map of North America* (Geological Society of America, New York, 1945.)
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15. The Chisos and Davis mountains of Trans-Pecos Texas are disjunct bodies of intrusive volcanic or extrusive rocks of early to mid-Tertiary age. They lie between the Sierra del Carmen (a lofty northwestern outpost of the Sierra Madre Oriental in Coahuila) and the Guadalupe Mountains (a southeastern outpost of the Sacramento Mountains of New Mexico), two massive Tertiary uplifts of pre-Tertiary rocks, chiefly limestones. Regardless of the age of the rocks, the existing montane landforms of high elevation in Trans-Pecos Texas are relatively recent, dating from mid-Tertiary (or later) block-faulting and emplacement of intrusive bodies, with uplift, especially during the Pliocene and Pleistocene [P. B. King, *Bull. Amer. Assoc. Petrol. Geol.* **19**, 221 (1935); ———, in *The Quaternary of the United States*, H. E. Wright and D. G. Frey, Eds. (Princeton Univ. Press, Princeton, N. J., 1965), p. 845]. Hence, limits are placed on the age of high-elevation habitat in the Chisos and Davis mountains, and therefore the time available for its colonization by existing vegetation.
16. D. S. Correll, *Wrightia* **3**, 128 (1965).
17. C. Darwin, *The Origin of Species* (Murray, ed. 6, London, 1889), p. 347; A. R. Wallace, *Island Life* (Macmillan, London, 1892), p. 257; H. N. Ridley, *The Dispersal of Plants Throughout the World* (L. Reeve, Ashford, England, 1930), p. 675; S. Carlquist, *Island Life* (Natural History Press, Garden City, New York, 1965), p. 9.
18. Although long distance transport of seeds, followed by successful establishment, must be regarded as a highly infrequent event, a significant number of such incidents probably occurs during time periods of more than 10^6 years. Nearly half of the 70 ligneous species which make up the bulk of montane vegetation in the Chisos and Davis mountains have small baccate fruits apt to be dispersed by a variety of frugivorous birds which pass the stony seeds or pits unharmed. A possible agent of dispersal for the heavier propagules of other mesophytic montane plant species of these isolated ranges is the band-tailed pigeon (*Columba fasciata* Say). A large, seed-eating bird with strong powers of flight, it possessses a capacious crop, or esophagal pouch, in which fruits and seeds are temporarily stored. Darwin long ago observed: "But the following fact is more important: the crops of birds do not secrete gastric juice, and do not, as I know by trial, injure in the least the germination of seeds; now after a bird has found and devoured a large supply of food, it is positively asserted that all the grains do not pass into the gizzard for twelve or even eighteen hours. A bird in this interval might easily be blown to the distance of 500 miles, and hawks are known to look out for tired birds, and the contents of their torn crops might be thus readily scattered" [C. Darwin, *The Origin of Species* (Murray, ed. 6, London, 1889), p. 308]. The band-tailed pigeon habitually fills its crop with the largest seeds and fruits, such as acorns (one of its principal foods) and greater numbers of smaller propagules, as of *Arbutus, Pinus, Prunus, Rhamnus, and Sambucus* [A. C. Bent, *U.S. Nat. Mus. Bull.* **16**, 353 (1932)]. It breeds in the montane forests of the Sierra del Carmen, Chisos, Davis, and Guadalupe mountains even at the present time and migrates or wanders extensively throughout the region, chiefly at higher elevations. The distance from the Sierra del Carmen in Coahuila to the Chisos Mountains across the Rio Grande is scarcely 50 km (as the pigeon flies, an hour's journey), and the extensive stands of *Pseudotsuga* (Douglas fir) in the Sierra del Carmen seem to be the most probable source of seed for colonization of the isolated Chisos Mountains. On the other hand, the lofty Davis Mountains, which display an anomalous lack of Douglas fir, are formidably remote from the *Pseudotsuga* seed sources in the Sierra del Carmen and the Guadalupe Mountains (distances of 200 and 150 km, respectively). For many of the Arctotertiary species in the Davis or Chisos mountains, such as the mesophytic deciduous trees *Acer grandidentatum, Quercus gravesii, Q. muehlenbergii*, and *Ostrya chisoensis*, the time period available for migration extends back into the Tertiary, perhaps for some millions of years (*15*), but seed sources and target areas on isolated mountain peaks were undoubtedly most extensive during pluvial phases of the Pleistocene, particularly for conifers of boreal character, such as *Pseudotsuga*.
19. Supported by NSF grant GB-1821. Radiocarbon ages were determined by Drs. Rainer Berger and W. F. Libby of the University of California, Los Angeles. I thank Dr. Barton H. Warnock of Sul Ross State College, Alpine, Texas, who discovered the principal midden site in Maravillas Canyon, and made available his collections of existing flora.
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3 June 1966

Butler, Missouri: An Unusual Iron Meteorite

Abstract. *The Butler iron meteorite has been found to have, with respect to other iron meteorites, an unusually high cobalt content (1.4 percent by weight), unusually high germanium contents in the kamacite and the taenite phases, and an unusually low cooling rate (0.5°C/10⁶ years). It is suggested that Butler formed in a different environment from that of the rest of the iron meteorites.*

Analyses of approximately 160 iron meteorites to date have revealed a very wide range of Ge concentrations extending from 400 parts per million (ppm) down to 0.03 ppm. As shown by Wasson (*1*), the Butler iron meteorite has an unusually high Ge content, 2000 ppm. This high Ge content, as well as the high Ge/Ni ratio, makes Butler an exception to two geochemical generalizations regarding iron meteorites (*1*). This exception implies that Butler may be unusual in other ways. Below I report the measurements of major element distributions and of the cooling rate of Butler, further showing its unusual characteristics.

The structure of the Butler meteorite, which has 16 percent (*2*) Ni (*1*), is transitional between a fine octahedrite and an ataxite. A photomicrograph of the meteorite is shown in the cover photograph. The large kamacite plates make up the well-defined Widmanstätten pattern typical of the octahedrites. The interior areas between the kamacite plates of the major pattern are regions of transformed taenite (plessite) which contain a micro-Widmanstätten pattern sometimes found in the ataxites. As shown by Goldstein and Ogilvie (*3*), this micro-pattern formed late in the meteorite's cooling history.

Analysis of the metallic phases of the meteorite with the electron microprobe showed that only Fe, Ni, Co, and Ge

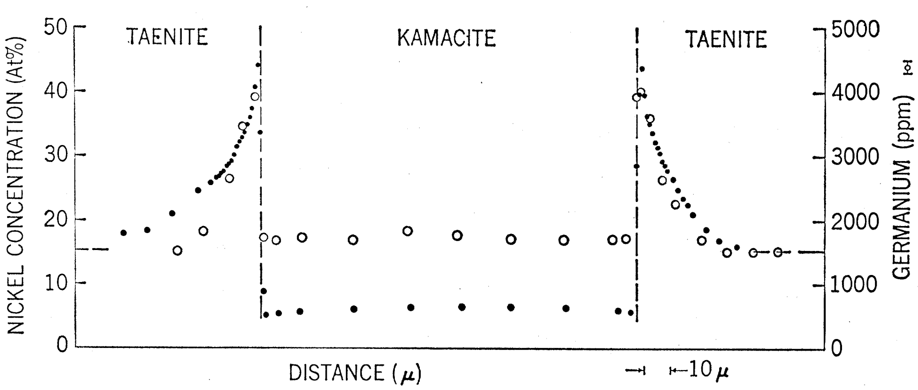

Fig. 1. Distribution of nickel (small filled circles) and germanium (open circles) in the Butler iron meteorite, which has 16 percent nickel by weight and 2000 ppm germanium. *At%*, atomic percent. The small vertical mark above the right-hand label represents the 95-percent confidence limits for germanium (± about 100 ppm).

are present in excess of 0.15 percent. The Fe and Ni concentration gradients were typical of those found in iron meteorites. The Ni content varied from 16 to 45 percent in taenite and from 6 to 6.5 percent in kamacite, except near the kamacite-taenite boundaries, where it was less than 6 percent. The Co content was, however, unusual. According to Krinov (*4*), the average Co content in fine octahedrites is 0.61 percent. The total variation in Co for all classes of iron meteorites, according to Lovering *et al.* (*5*), is from 0.38 to 0.75 percent. Butler contains 1.7 percent Co in kamacite, 0.6 percent Co in taenite, and 1.45 percent Co in plessite. The average Co content, 1.4 $\pm$ 0.1 percent, is almost twice as much as that found in any other iron meteorite to date.

The distribution of Ge in the meteoritic phases was measured with the electron microprobe, by use of a procedure described by Goldstein and Wood (*6*). Germanium concentrates only in kamacite and taenite. The kamacite bands which make up the typical Widmanstätten pattern of the meteorite contain 1700 $\pm$ 50 ppm Ge. The kamacite areas in plessite, less than 50 μ in width, contain 1550 $\pm$ 50 ppm. Typical Ge and Ni concentration gradients in kamacite and taenite are shown in Fig. 1. The Ge follows the Ni, and the maximum Ge content in taenite is over 4000 ppm (0.4 percent). The distribution of Ge with respect to Ni and kamacite band size is typical of that found for meteorites with overall Ge greater than 20 ppm (*7*). However, the absolute Ge contents of the metallic phases is much greater than in any other iron meteorite.

The cooling rate for the temperature range in which the Widmanstätten pattern developed (700° to 300°C) was also determined. This was accomplished by comparing the measured concentration gradients in several kamacite-taenite areas with gradients calculated by a theoretical growth analysis for the Widmanstätten pattern (*3, 8*). The calculated gradients vary with the cooling rate assumed. The cooling rate is determined when a fit is obtained between the measured and calculated gradients.

The relatively high levels of Co and Ge present in Butler have little or no influence on the Ni contents of the metallic phases. This can be seen by comparison with measured Ni values for other meteorites (*9*). The Co and Ge may also have an influence on the diffusion coefficients which control the Widmanstätten growth process. However, the diffusion coefficients in the temperature range (700° to 300°C) are not known to within $\pm$ 50 percent of their actual value. The influence of the Co and Ge is probably less than the uncertainty in the diffusion coefficients, and therefore was not considered further. The cooling rate determined for Butler is $0.5°C/10^6$ years, with an estimated precision of ± 30 percent. This cooling rate is lower by a factor of 2 than any cooling rate determined for iron meteorites in the study of 27 iron and stony iron meteorites by Goldstein and Short (*8*). Thus the cooling history for Butler appears to be unique.

Butler is indeed an unusual meteorite. It not only contains more Ge and Co than any other iron meteorite, but also cooled more slowly than any other iron meteorite measured to date. It is probable that Butler formed in a different environment from that of the rest of the iron meteorites.

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17 June 1966

Butler, Missouri: An Iron Meteorite with Extremely High Germanium Content

Abstract. *The Butler iron meteorite has been found to have a germanium concentration of 2000 parts per million, which is about five times higher than the highest concentration that has been measured previously in an iron meteorite. The gallium concentration is 87 parts per million, which is among the highest concentrations found in these objects. The nickel content is 16.0 percent, the second highest nickel concentration known in a meteorite displaying a Widmanstätten pattern. The high Ge/Ni ratio, as well as the association of a high nickel content with high gallium and germanium contents, make this object an exception to two geochemical generalizations regarding the iron meteorites.*

During the past 10 years a large body of evidence has been gathered on the Ge concentration of iron meteorites. Analyses of approximately 160 irons have revealed a very wide range of concentrations that extend from 400 parts per million (ppm) down to 0.03 ppm. There are arguments which show that the Ge/Ni ratio in the group of irons with about 400 ppm (Ga-Ge group I) is the maximum to be expected for an undifferentiated core of a meteorite parent body. This paper is a report of the discovery of an iron meteorite, Butler, which has a Ge content five times higher than the previous high measured in an iron meteorite, and a Ge/Ni ratio that is higher than the expected maximum mentioned above. The object also has a Ni content much higher than that found in the only previous analysis.

The Butler iron meteorite was plowed up by a farmer sometime before 1875 (*1*). At that time the object weighed about 40 kg, and pieces of it were soon distributed to many different meteorite collections throughout the world (*2*). The Prior-Hey catalog of meteorites (*3*) shows that most of the remaining material is in the Mineralogical Museum at Harvard where 14 kg is located. There has been only one study of the chemical composition of the object prior to my work. In 1877 J. Lawrence Smith (*4*) published an analysis that showed a nickel content of 10.02 percent, a value that this report shows to be 6 percent too low.

The structure of the meteorite is quite unusual. A distinct Widmanstätten pattern is observed, but the kamacite lamellae are extremely fine and discontinuous. The bulk of the object consists of plessite. Most researchers have assigned Butler to the structural class of "finest octahedrites," but Buchwald (*5*) had recently proposed a new catalog of "ples-