Vol. XX No. 4 SCIENTIA SINICA July - August 1977

A PRELIMINARY SURVEY ON THE KIRIN METEORITE SHOWER

Joint Investigation Group of the Kirin Meteorite Shower, Academia Sinica

(中国科学院"吉林陨石雨"联合考察组)

Received October 14, 1976.

ABSTRACT

Made in the present paper is a preliminary report on the phenomena of the fall of the Kirin meteorite shower, its distribution area and characteristics, the meteor's flight, and its mineral constituents, structure and chemical composition. The results of the studies have provided evidence that the Kirin meteorite does belong to ordinary H-group chondrites, or is referred to as olivine-bronzite chondrites.

At about 15 hr (Peking Time) on March 8, 1976, a meteorite shower of unprecedented scale occurred in the northern part of the district of Kirin, Kirin Province. On the basis of preliminary observations made by the Kirin Municipal and Provincial Meteorite Shower Investigation Group, a joint investigation group formed by the Kweiyang Institute of Geochemistry, the Institute of Geology, the Institute of Mechanics, and the Purple Mountain Observatory of Academia Sinica, as well as the Peking Planetarium and Peking University went there to conduct an on-the-spot investigation from March 11 to May 8. Under the leadership of the Kirin Provincial Party Committee and Kirin Municipal Party Committee, the scientific investigation work was warmly supported and helped by the broad masses of workers, peasants, and soldiers in that area. The joint group interviewed about one thousand eyewitness, held more than 40 discussions, took measurements, and made drafts, analyses, and identifications on the spot. The first-hand observational data given by the broad cadres and masses provided the group with rich and accurate research information and laid a good foundation for further study of the Kirin meteorite shower.

I. PHENOMENA OF THE FALL

1. *Fireball and Sound of the Breakup*

At about 15:01 hr on March 8, 1976, a red fireball bigger than the full moon and moving southwestward was sighted by some dozens of townspeople of Hsinglung ($\lambda 127°05'$ E, $\varphi + 46°26'$ N), Payen county Heilungkiang Province. During the fireball's flight over a distance of 300—400 km, the incandescent fireball was being observed overhead by thousands of people in the Tienteh People's Commune and Chishu People's Commune of Shulan county, Kangyaochen, Takouchin and the northern outskirts of the city of Kirin. At that time, the sky was overcast with ten-

tenths thin clouds, cirrus (Ci) densus at about 12 km above ground, and altocumulus (Ac) at 2—4 km level. The fireball, white reddish in colour, was twice as big as the apparent solar disk. The bluish-rimmed fireball gave off dazzling rays with a brilliant trail of light and whirling clouds of smoke and dust.

During the flight of the fireball, the meteorite body underwent several small explosions and many small fragments fell one after another. A violent breakup occurred when the main body of the fireball was over the northeastern part of the Chinchu People's Commune on the northern outskirts of the city of Kirin and the brilliance of the bursting flash was observed by the people nearby. Some comrades of the work team of the Kirin Municipal Party Committee saw that a yellow fireball suddenly gave off an intense flash as its diameter expanded to more than 2 m. From it a smaller yellow fireball, with a yellow trail of light behind, was cast off and continued its course ahead. Some observers found that the violent breakup gave rise to three small fireballs —— the largest one was as big as the full moon, while the smaller ones looked like footballs, and all three travelling south-westward in procession one after another. These three fireballs were later named respectively Meteorite No. 1, 2, 3 of the Kirin meteorite shower.

The sounds produced by the shock wave during the fireball's rapid passage through the air, the thunderclap of its violent breakup and a series of rolling thunder like echoes altogether lasted 4—5 min and were audible to about one million people over an area of about 200 km^2.

The air-wave generated by the shock wave shook everything on the ground, made the nearby high tension transmission lines quake, pushed many doors and windows open, shook and toppled the goods in the department stores in the city of Kirin. Most of the meteorites fell to the ground at quite a low speed, generally less than 300 m per sec and their temperature on touching the ground ranging from 50°—80°C.

2. *Phenomena of the Fall of Meteorite No. I*

Meteorite No. I fell in the eastern part of the village of No. 10 production team of the Kaoshan Production Brigade of the Huapichang People's Commune, Yungchi county, Kirin Province. Meteorite No. I hit the ground 65 m away from the nearest house. The geographic coordinates are at λ 126°12′52″ E and φ + 44°01′31″ N.

When Meteorite No. I was falling, three commune members and three children 30 m away from the landing site witnessed the whole or part of the phenomenon, and so did more people in the distance. They suddenly heard a sound like a boom of a supersonic plane with a sharp sound followed. A huge greyish mass like a huge jar fell from high above and pitted the ground, giving off a violent breakup. The impact shattered window glasses previously cracked, made the clay fall from the ceiling of the rooms and pushed the unbolted doors open.

The meteorite hit the ground, giving off an appalling roar. Clumps of frozen soil intermixed with meteorite fragments were scattered west of the centre, of which the lighter were thrown farther, and the farthest being 150 m away. Following the

sound and shake as the meteorite smashed through a layer of frozen soil, a cloud of yellow dust and smoke rose near the centre. Observed from one km away, the rolling dust gradually formed a small mushroom cloud to a height of about 50 m. The cloud was so dense that everything behind it was obscured from view. A few minutes later when the dust was dispersed by the wind, a big crater was seen on the ground. The mouth of the crater was elliptic in shape, major axis 2.1 m, minor axis 2 m. Fine dust gathered in the crater (Photo 1). On the eastern rim of the pit-mouth, there was a stria with a width (north-south) of 1.4 m. The occurrence of the stria was: azimuth —— 257.5°, inclination —— 42°. The walls of the crater were steep and the rim around the crater was slightly inclined. The inclination of the central line (axis) of the crater was 65°. An upturned lip which was formed under the compression and by sputtered terrestrial materials accumulated as the meteorite smashed into the frozen soil encircled the crater. The eastern side of the lip was connected with the stria while the western side was 1.4 m away from the mouth of the crater, with the major axis of the lip being 4.1 m, and the minor axis 3.4 m. A layer of 0.2 m frozen soil inside the lip was cut away when the meteorite pitted the ground . It was 0.65 m high between the maximum height of the lip and the inside bottom of it.

Under the unified leadership of the Kirin Municipal Party Committee, the workers from electric industry, communication and transportation and construction departments, and local poor and lower-middle peasants dug the crater of Meteorite No. I. The soil through which Meteorite No. I passed was composed of several sections (inclined distance 6.5 m): (i) surface soil, 1.9 m (1.7 m frozen soil is included); (ii) black clay layer, 0.15 m; (iii) grey-bluish clay layer, 0.45 m; (iv) red sub-sand layer, 0.8 m; (v) greenish clay layer, 0.3 m; (vi) sand layer with greenish clay, 0.25 m; (vii) black clay layer down to the bottom of the crater with a small amount of limestone gravels (Fig. 1, Photo 2).

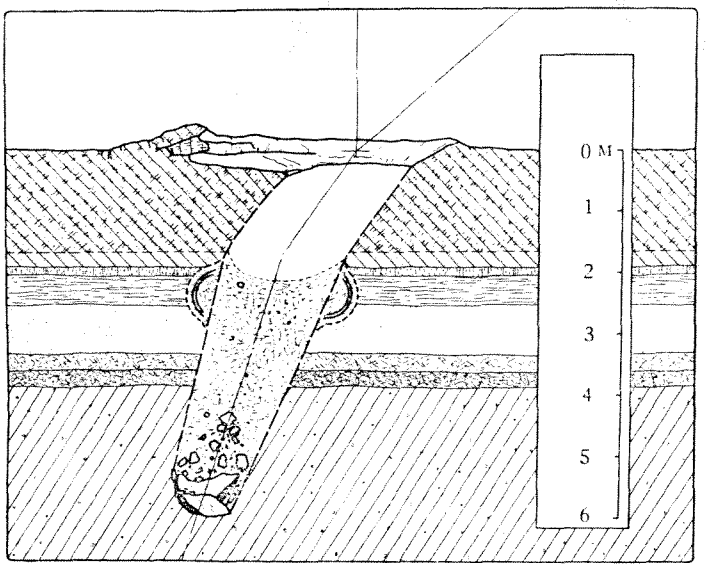

Fig. 1. The section of Meteorite No. 1 crater.

Meteorite No. I was shattered as it passed through the layer of frozen soil. The total net weight of the pieces collected in crater No. I amounted to 1,770 kg; the main specimen weighs 1,170 kg; the other fragments weigh 600 kg. The surface of the restored main specimen was marked by a number of parallel fusion flowlines generated at different developments. The morphological property of Meteorite No. I and the flowlines and fractures on its surface showed that the original weight of Meteorite No. I when it was falling into the crater, must have exceeded 2 metric tons (including the sprinkling fragments still in the crater).

Meteorite No. I is the biggest of the Kirin meteorite falls as well as the biggest aerolite that has been preserved so far in the world (Photo 3).

II. Distribution Area and Its Characteristics

The Kirin meteorite shower was scattered over an area of many hundreds of square kilometres embracing 7 communes and 18 production brigades with a population of more than 100,000 in Yungchi and Chiaoho counties and the northern outskirts of the city of Kirin in the Kirin district. The geographic coordinates are at λ 126°10′—127°10′ E and φ + 43°55.5′—44°3.2′ N. The distribution of the Kirin meteorite shower showed obvious regularity (Fig.2). Main fragments were scattered in a narrow strip of land of which the length (from east to west) was 72 km, and the

Table 1

The Sites and Weights of Meteorites of Kirin Meteorite Shower and the Occurrence of Craters

Meteorite Site	Weight of Meteorite in kg	Occurrence of craters (direction, angle of inclination)
No. 10 Production Team, Kaoshan Production Brigade, Huapichang People's Commune, Yungchi County	net 1,770 (originally >2,000)	257.5°, ∠42° (according to the stria of the slickenside on the ground)
No. 8 Production Team, Tahuangti Production Brigade, Kutientzu People's Commune, outskirts of Kirin City	ca. 400	227.5°, ∠55°
No. 2 Production Team, Santaitzu Production Brigade, Chiuchan People's Commune, outskirts of Kirin City	123.5	257.5°, ∠55°
Chaochiakangtzu, Chiuchan People's Commune, outskirts of Kirin City	70	250°, ∠60°
Nanlan Production Brigade, Chinchu People's Commune, outskirts of Kirin City	25—52.5	245°, ∠65°
No. 1 Production Team, Chiutsuo Production Brigade, Chinchu People's Commune	20	150°, ∠77°
Tungshanpo, Chiutsuo Production Brigade, Chinchu People's Commune	15—20	150°, ∠87°
No. 2 & No. 5 Production Teams, Lichia Production Brigade, Tatun People's Commune, outskirts of Kirin City	5—12	115°—130°, ∠55°—60°
Huangchin Production Brigade, Chiangmifeng People's Commune, Yungchi County	1—5	110°—125°
No. 2 Production Team, Tungfanghung Production Brigade, Chiangmifeng People's Commune, Yungchi County	0.5—1	160°—205°
Tienkang People's Commune, Chiaoho County	0.5	direction ES

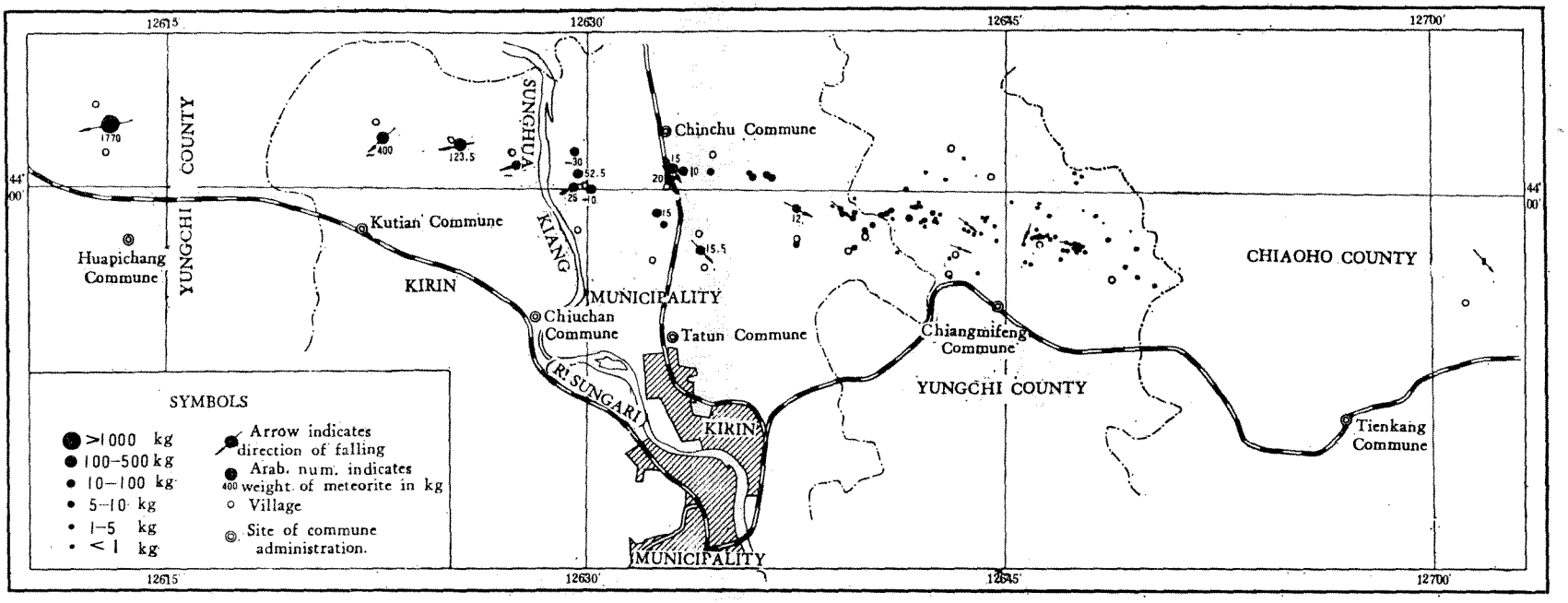

Fig. 2. Index map of the distribution of the Kirin meteorite shower.

width 8.5 km. Plotting against the distribution of the main mass taken as the axis of an ellipse, the shower was distributed within an elongated ellipse. The azimuth of the major axis of the ellipse was 94°—274° and the area of the ellipse approximated to 480 km² —— the largest distribution area of the meteorite shower in the world. At the westernmost point of the ellipse was located Meteorite No. I; east of it meteorites Nos. 2, 3,..., successively, and their weight decreased progressively (Fig. 2, Photo 4). The most clustered area was the Chiangmifeng People's Commune with an average of 10 pieces per square kilometre.

The distribution of the small meteorite fragments was not uniform either, but locally concentrated such as Tengchiaputzu, Tungfanghung, and the northern part of the Huangchintun in the Chiangmifeng People's Commune, Chintun in the Tatun People's Commune, the Chiutsuo and Nanlan Production Brigades in the Chinchu People's Commune, etc. The direction of every meteorite fallen in the west of λ 126°30′ E was SWW; in the east of λ 126°30′ E, SEE.

III. The Flight of the Meteorite

1. *The Position, Height, and Time of the Breakup of the Meteorite*

At 15:00 hr on March 8, 1976, the heliocentric longitude of the earth was 168°, the longitude of the sun was 348°, its distance from the vernal equinox was 12°. At that time the geographic longitude of the Kirin district was at the posterior in respect to the forward direction of the earth. In view of the elevation angle of the meteorite being comparatively small, the meteorite overtook the earth from behind along the direction of the earth's revolution around the sun. The velocity of the meteorite was, relative to that of the earth's motion, more than 10 km/sec.

When the meteorite flew off 20 km high, its speed was estimated at 5—10 km/sec. The surface temperature of the meteorite probably reached some thousands to 10,000°C. Superpressure probably reached one hundred atm. The meteorite broke up violently probable besause it was compressed by the strong shock wave and affected by thermal stress through the flight. Based on the characteristics of the meteorite shower's distribution, the azimuth and inclination of the fall, position, height, and time of the breakup can be analyzed as follows.

All meteorites falling in the west of the Nanlan Production Brigade, Chinchu People's Commune, weigh more than 50 kg and the falling direction was from NEE to SWW approximately; those falling in the east of the Chiutsuo Production Brigade, Chinchu People's Commune, weigh less than 20 kg, and the falling direction was from NW to SE. The inclination of the meteorites near the Chiutsuo Production Brigade was steep (>75°). In consideration of the feature of the fall, the projection point of the breakup was likely in the east (slightly to the north) of Chinchu People's Commune.

The cadres and commune members in the Chinchu People's Commune administration sighted the flash and heard the sound of the breakup coming from the south, while those in the Lichia Production Brigade, Tatun People's Commune, observed them coming from the north. The distance between these two communes is 8 km, showing that the place of the meteorite's breakup was in the northeast of the Chinchu

People's Commune. According to the report made by the commune members in Tungshanpo, Chiutsuo Production Brigade, Chinchu People's Commune, the sound of the breakup was exactly over their heads, meanwhile they observed three meteorites falling in three different directions.

On the basis of the occurrence of the meteorite craters Nos. 1, 2, 3, 4, and the azimuth and inclination of the meteorites falling in the Nanlan, Chiutsuo and Tatun Production Brigades, it was postulated that the meteorite probably broke up when it was 17 km high above the ground in the northeast of the Chinchu People's Commune; in the meantime the dynamic pressure was at its maximum, and so was the resistance force. After the breakup, several big fragments of the meteorite kept on moving southwestward, while some smaller ones, because of small mass and strong influence of air resistance, quickly reached the ultimate speed and fell in the Chinchu People's Commune, Tatun People's Commune, and partly further to the east. The smaller meteorites were forced mainly by upperwind to reverse the direction of the fall. The meteorites in Chiangmifeng possibly fell in this manner.

During the big meteorite's flight at high speed, strong shock wave was produced at its head. When the shock wave passed the ground, people heard the intensive sound of the breakup and the boom caused by echoes. The Kirin and Fengman seismographic stations registered the shock wave separately.

After the breaking up over the Chinchu People's Commune, Meteorite No.I went on flying and sank 6.5 m deep into the ground accompanied with thunderous sound, evoking a violent ground vibration. The Kirin and Fengman seismographic stations also recorded the signals of the vibration. The Kirin seismographic station took the record at 15:2:50 hr, while the Fengman at 15:2:46 hr. According to the local stratigraphic texture and the data of propagation speed of the seismic wave, and taking the velocity of seismic wave as 4,000 m/sec, we calculated that the Meteorite No. I hit the ground at about 15:2:36 hr.

2. *The Meteor's Direction of Flight in the Atmosphere and Its Orbit in the Outer Space*

As the meteorite had a cosmic speed of some kilometres per second at its breakup and the breakup itself could only produce a small additional speed, the main flight direction would not be influenced by it. On the whole, directions of the flight of Meteorites Nos. 1, 2, 3, 4 all characterized the meteor's flight direction before its breakup, namely from east slightly northward toward west slightly southward.

Most of the small meteorites falling in the Tienkang People's Commune, Chiaoho county and the Chiangmifeng People's Commune, Yungchi county were probably scattered owing to a series of disintegration of the meteorite during its flight through the atmosphere. At 10 km high above, the wind direction was then from the west with little turn to north and the velocity of the wind was 30—50 m/sec. Such great speed greatly affected the direction of the small meteorites' flight.

IV. Characteristics of the Meteorite's Feature

The Kirin meteorites have a great variety of shapes and sizes (Photo 5). Meteorites Nos. 1, 2, 3 are polyhedra. The weight of the main body of Meteorite No. I

amounts to 1,170 kg, volume —— $117 \times 93 \times 84$ cm^3 (maximum dimension), average volume —— $100 \times 85 \times 55$ cm^3. Meteorite No. 2 weighs about 400 kg. Meteorite No. 3 weighs 123.5 kg, volume —— $30 \times 40 \times 50$ cm^3. The meteorites less than 100 kg are usually irregular polyhedra. The meteorites less than 5 kg generally are long hexahedra or close to isometric polyhedra.

The surfaces of the meteorites were generally covered with depressions and burn pits. The depressions presented directive arrangement in the shape of finger, tongue, leaf, petal and so on, the dimension of which might be 3—5 × 4—7 cm^2 and 1 × 1 cm^2. The depth of the depression mostly was 5 mm, but that of particular ones came to 20 cm. The distribution density of the depressions was generally 1.86—2.27/10 cm^2, and 0.4—0.5/cm^2 in certain parts (Photo 6).

The surfaces of the meteorites are covered with black or brown fusion crusts with 0.5—1 mm in thickness. The fusion crusts were formed time and again owing to the meteorite's successive fragmentation in the atmosphere. By comparing with the first fusion crust, the second, third and fourth fusion crusts' depressions became smaller successively and the degree of lustre decreased as well. The surface of the latest fusion crust was very rough and the depression developed incompletely. Cracks developed owing to quick cooling could be seen easily on fusion crusts, and also the papilla and fine groove formed by the molten materials.

The surface of Meteorite No. I is marked by a number of parallel flowlines of 10—100 cm in length and 1—20 cm in width. The stretching direction of the flowlines of the fusion crusts was parallel to the flight direction of the meteorite. The degree of development played an important role in the meteor's disintegration.

V. Mineral Constituents, Structure, and Chemical Composition of the Kirin Meteorite

1. *Mineral Composition and Chondrulitic Structure*

The fresh section of the Kirin meteorite is greyish in colour, and the chondrules can evidently be seen. The diameter of the biggest chondrule is from 2 to 3 mm, even to 5 mm, but 0.5—0.15 mm in general. Sometimes, olivine crystals and pyroxene prismatic crystals can be seen on the section plane too.

X-ray diffraction analyses, X-ray powder analyses (described by Debye and Scherrer) and identification under polarizing microscope preliminarily reveal the mineral constituents of the Kirin meteorite as given in Tab. 2.

Olivine crystals in the thin sections are commonly colourless and transparent. The grains are mainly subhedral or irregular, sometimes idiomorphic-granular (Photo 7), biaxial negative, $2V = 83.5°(-)—86.5°(-)$, $N_g = 1.6965—1.7089$, $N_m = 1.6778—1.6867$, $N_p = 1.6614—1.6790$, showing that the olivine can be attributed to chrysolite and forsterite ($Fa_3—Fa_{18}$). The pyroxenes mainly are enstatite and bronzite, and optical identification gives the constituents of ($En_{93}Fs_7—En_{89}Fs_{11}$).

The metallic minerals in the polish-section are irregularly granular or porphyritic (Photo 8). The proportion of the metal facies in the meteorite is about 20%.

Table 2

Mineral Constituents of the Kirin Meteorite

Transparent Mineral Facies		Opaque Mineral Facies		
Major Mineral	Minor Mineral	Major Mineral	Minor Mineral	Secondary Mineral
Olivine	clinopyroxene	kamacite	chromite	magnetite
Orthopyroxene	plagioclase, whitlockite	taenite	schreibersite	
(bronzite enstatite)	α-cristobalite orthoclase	troilite		

Table 3

The Content of the Main Elements in the Kirin Meteorites

Locality and Original No. / Element	Meteorite No. 1	Meteorite No. 2	Lichia No. 5 Production Brigade, Tatun People's Commune	Huangchin Production Brigade, Chiangmifeng People's Commune
	G-2	G-37	G-61	G-62
SiO_2	35.94	36.80	37.54	37.06
Al_2O_3	2.00	2.18	2.28	2.20
TiO_2	0.10	0.10	0.10	0.10
Cr_2O_3	0.48	0.51	0.51	0.52
FeO	13.88*	6.64	5.60	6.93
MnO	0.28	0.30	0.29	0.29
MgO	21.19	22.92	23.34	23.12
CaO	1.79	1.81	1.79	1.96
Na_2O	1.07	0.82	1.04	1.02
K_2O	0.12	0.12	0.12	0.12
H_2O^+	0.01	0.14	0.12	0.24
H_2O^-	0.09	0.09	0.04	0.07
P_2O_5	0.27	0.27	0.28	0.28
Fe	16.02*	20.38	19.86	19.15
Ni	1.84	1.80	1.73	1.76
Co	0.088	0.086	0.080	0.082
Cu	0.011	0.010	0.010	0.010
FeS	5.29	5.31	5.26	5.29
Sum	100.47	100.29	99.99	100.20
Fe (total)	30.17	28.91	27.55	27.90
Fe (sulphide facies)	3.36	3.37	3.34	3.36
Fe (sulphide facies + metal facies)	19.38	23.75	23.20	22.51
Fe (silicate facies)	10.79	5.16	4.35	5.39

* The content of Fe in Meteorite No. I decreases as the consequence of its partial oxidation after falling, while that of FeO increases.

The minerals constituting chondrules are fine-granular or porphyritic. The matrix is composed of olivine, clinopyroxene, and opaque minerals. The distribution of the chondrules in matrix is rather uniform with the content of about 20% in common cases.

The chondrules can be divided into olivine chondrule (equigranular and seriate) (Photo 9), orthopyroxene chondrule (mainly fan-shaped, fibre-bundle-shaped, radial or cross-shaped) (Photo 10), olivine-orthopyroxene chondrule (barred and prophyritic) and cryptocrystalline chondrule, in which there are often fibre-bundle-shaped orthopyroxene generated by devitrification.

The figures of chondrules are commonly clear, but the boundaries of a small amount of chondrules are rather vague. In the thin sections one can often find some mineral crystals intensively twisted or smashed or ruptured. Some minerals show optically wavy extinction.

2. *Chemical Composition*

Four representative samples from the Kirin meteorites have been analysed by means of atomic absorption spectrometry, flame photometry, colorimetry, and classical gravimetry and volumetry. The contents of the main elements are tabulated in Tab. 3.

Some related chemical parameters of the Kirin meteorite:

Fe/SiO_2	= 0.839	0.786	0.734	0.753
Fe°/Fe	= —	0.705	0.721	0.686
SiO_2/MgO	= 1.696	1.606	1.608	1.603
Ni/SiO_2	= 0.0515	0.050	0.046	0.048
Co/SiO_2	= 0.0024	0.0023	0.0021	0.0022

It is concluded from the results of the chemical analyses of the Kirin meteorites and the related data, such as Fe/SiO_2, Fe°/Fe, SiO_2/MgO, Ni/SiO_2, Co/SiO_2, that the Kirin meteorites belong to ordinary H-group chondrites.

VI. Conclusion

The Kirin meteorite almost followed the trajectory of the earth around the sun with the relative velocity of more than 10 km/sec and overtook the earth at 15:00 hr on March 8, 1976. The Kirin meteorite plunged into the atmosphere at a low angle of incidence, with the direction from east (little deviation to north). During the rapid passage through the atmosphere, the Kirin meteorite collided with air molecules and the friction against the earth's atmosphere was bound to make it burn and incandesce. A strong shock wave was produced at the head of the meteorite giving out a thunderous sound of violent breakup. During the meteorite's flight, many small disintegrations took place and a violent breakup occurred when the meteorite was about 17 km high over the northeastern part of the Chinchu People's Commune.

The Kirin meteorite shower was formed by the meteorite fragments falling in total weight of about 4 metric tons. The main body of the meteor —— Meteorite No. I hit the ground at about 15:2:36 hr.

Meteorite No. I is the biggest in the world, weighing 1,770 kg. The distribution area of the Kirin meteorite shower was about 500 km^2 —— the biggest in scale in the world.

A preliminary study of the meteorite's mineral constituents shows that the Kirin meteorite shower belongs to ordinary H-group chondrites, or it can be named as olivine-bronzite chondrites.

The Kirin meteorite shower has provided favourable conditions for the study of meteorites in our country. It will give an impetus to the development of the related disciplines. As a result of the unified leadership of the Party and following the principle that scientific research must serve the proletarian politics and serve the socialist revolution and construction, the Investigation Group of the Kirin Meteorite Shower has gained great achievements in a short period of time. **"Nothing is hard in this world if you dare to scale the heights."** Under the guidance of Chairman Mao's revolutionary line and the wise leadership of Chairman Hua, we will resolutely climb up one peak after another in meteorite research.