Meteoritics & Planetary Science 33, A193–A196 (1998)

Report

The Galkiv meteorite: A new H4 chondrite from Ukraine

V. P. SEMENENKO* AND A. L. GIRICH

State Scientific Centre of Environmental Radiogeochemistry National Academy of Sciences of Ukraine, Palladina 34A, Kyiv-142, 252180, Ukraine

*Correspondence author's e-mail address: center@radgeo.freenet.kiev.ua

(Received 1997 December 15; accepted in revised form 1998 April 9)

Abstract–The Galkiv chondrite is a single 5 kg stone that fell in the Chernigov region of Ukraine on 1995 January 12. The composition of olivines in the meteorite indicate that Galkiv belongs to the H group of ordinary chondrites. Although the heterogeneity of olivine corresponds to a petrologic type 5 and the heterogeneity of low-Ca pyroxene suggests the chondrite is type 3, clearly defined chondrule boundaries, the presence of clinopyroxene, cryptocrystalline glass and rare grains of feldspatic plagioclase, structural evidences of shock metamorphism and very low level of terrestrial weathering allow us to classify the meteorite as an H4 chondrite of shock stage S3 and weathering grade W0.

INTRODUCTION

The Galkiv meteorite (Fig. 1) fell on 1995 January 12 at 11:30 (Central European Time) next to the village of Galkiv in the Chernigov region, Ripky district, Ukraine (51°41'N, 30°47'E). The stone fell after a sonic boom was heard by a drayman, V. M. Leonenko. After falling, the black stone bounced slightly and rolled on a grassy marsh (Fig. 2). The fall frightened Mr. Leonenko and his horse. He rushed to the village of Galkiv.

A sonic boom like that from a jet-propelled aircraft was heard by many of Galkiv's residents. Later the same day, the black stone weighing 5 kg was recovered by V. M. Serdiuk using the information of V. M. Leonenko and was given to the Galkiv school.

In 1996 February, the main part of the meteorite was taken to the Committee of Meteorites of National Academy of Sciences (NAS) of Ukraine from the Ripky Museum of Local Lore where it had been stored by a professor of the Chernigov Pedagogic Institute, I. K. Koval, and the head of the Museum, O. I. Zhyla (Fig. 1). At present, the main mass of the meteorite is stored in the Museum of Natural History of NAS of Ukraine and a smaller piece is in the possession of the Committee of Meteorites. An attempt by coworkers of the Ukrainian Committee of Meteorites to find additional samples of the meteorite in the environs of Galkiv was unsuccessful.

ANALYTICAL PROCEDURES

Two hundred grams of material was cut from the main part of the meteorite. Twelve polished sections with a total area of 17.46 cm^2 and two thin sections with a total area of 2.93 cm^2 were prepared for a petrographic study by reflected and transmission light microscopy and electron microprobe analysis. A few chondrules and their fragments were taken off for a scanning electron microscope (SEM) study of their surface and mineral compositions with a REM-100u (Ukranian SEM). The composition of minerals in the polished sections was studied with a JCXA-733 (JEOL Superprobe) electron microprobe, using 15 kV accelerating voltage for silicates and 25 kV for metallic phases and beam currents of 10 nA with a 2 μm diameter electron beam, and ZAF data correction. Analytical errors are 1.5% relative for major elements and 0.03% absolute for minor ones.

RESULTS

The meteorite was initially one individual sample with a black 0.5 mm thick fusion crust. The fusion crust has a striated pattern that indicates the stone's orientation during its flight through the atmosphere. The meteorite has a rounded pyramidal shape. The interior of the chondrite is fresh and is grey in colour. Chondrules and their fragments are clearly visible between the fine-grained matrix minerals. Most chondrules are grey. Some of them are dark grey

FIG. 1. Head of the Ripky Museum, O. I. Zhyla, with the Galkiv chondrite outside the Ripky Museum. 1996 February.

FIG. 2. Witness of the Galkiv meteorite fall, V. M. Leonenko (right), and villagers with Kyiv meteoritic group by the site of the chondrite fall. 1996 May.

or light grey in colour. The cut surface of the meteorite is characterized by a quantity of metal particles which is usual for H chondrites.

Mineralogy

The Galkiv chondrite is composed of chondrules, chondrule fragments and matrix. The chondrule:matrix ratio is typical of ordinary chondrites. In polished slab (Fig. 3a) and thin section, the chondrules have clearly defined boundaries. Porphyritic olivine and olivine-pyroxene, granular olivine-pyroxene, barred olivine, rarely barred pyroxene (Fig. 3b) and radial pyroxene chondrules are present. There are also small cryptocrystalline chondrules with globular shape. Some of them are partially or completely embedded into larger, predominantly porphyritic chondrules.

Cryptocrystalline chondrules and the mesostasis inside the porphyritic and barred chondrules are composed of poorly devitrified glass of brown or sometimes grey colour. Many porphyritic chondrules contain skeletal (hopper) silicate crystals. An SEM study of the surfaces of a selection of chondrules and their fragments revealed different morphological features. Some chondrules contain signs of collisions with other chondrules or they contain embedded smaller ones (Fig. 3c). The smooth surfaces of the cryptocrystalline chondrules have fine granular sculpture with large quantities of pores (Fig. 3d). Growth steps are visible on the faces of the crystals, disposed on the chondrule surface.

The matrix has a granular texture composed of silicates and larger particles of metal and troilite. Some interchondrule areas of matrix contain highly porous fine-grained silicate aggregates like those in the Saratov chondrite (Semenenko *et al.*, 1992a,b).

The meteorite contains olivine, low-Ca pyroxene, Ni-Fe, troilite, and minor amounts of high-Ca pyroxene, chromite, feldspatic plagioclase, phosphates, metallic Cu and rare grains of spinel (Fig. 3e) and quartz. Chondrules and matrix have a similar mineral compositions but differ by a higher quantity of metal and troilite in the matrix.

The composition of olivine $Fa_{17.4-19.4}$ (PMD = 2) is nearly homogeneous, and low-Ca pyroxene varies in the wide range corresponding to $Fs_{8.34-22.0}En_{77.1-90.4}Wo_{0.08-6.49}$ (PMD = 7) (Table 1). Some olivine grains contain up to 0.25 wt% P_2O_5. This feature of olivine composition can not be explained by phosphate contamination because of the absence in these analyses of CaO. A more detailed study of P-containing olivine grains must be done in the future. The presence of a slightly higher concentration of TiO_2 in a few olivine analyses may be used as an indirect indication of presence of ilminite, although we did not find in Galkiv this usual accessory mineral for ordinary chondrites. High-Ca pyroxene is present as separate grains or rims on low-Ca pyroxene. Its composition varies in the range $Fs_{2.09-13.5}En_{46.8-75.3}Wo_{11.2-49.9}$ (Table 1).

Feldspar occurs in chondrules and matrix as rare rounded or lath-shaped grains. Some of them are polysynthetically twinned (Fig. 3e). The composition of two lath-shaped grains falls into distinct groups: an anorthite-rich (SiO_2 = 47.6; Al_2O_3 = 33.8; CaO = 16.6; Na_2O = 2.36; FeO = 0.24; P_2O_5 = 0.22; Cr_2O_3 = 0.05; K_2O < 0.02; total = 100.90 wt%; $Ab_{20.4}An_{79.5}Or_{0.11}$) and an anorthite-poor (SiO_2 = 66.6; Al_2O_3 = 20.3; CaO = 0.65; Na_2O = 9.84; FeO = 0.65; P_2O_5 = 1.53; Cr_2O_3 = 0.12; K_2O = 1.36; total = 101.02 wt%; $Ab_{88.7}An_{3.25}Or_{8.07}$). The first feldspar is polysynthetically twinned and composes a rare diopside-plagioclase chondrule with spinel. The second one is associated with phosphate-chromite-metal in the matrix. Cryptocrystalline feldspathic material inside porphyritic and barred chondrules corresponds to two distinct compositional groups (Table 1).

Metal particles are dispersed throughout the chondrite. The largest grains are irregular in shape and are located in the matrix. Some of them have sinuous edges like corrosion borders and contain numerous inclusions of silicates, phosphate and rarely of chromite. The globular shape of the metal is typical for chondrules. Etching of metal grains shows the metal is composed predominantly of kamacite and rarely of taenite (Table 2). The latter associates as zonal taenite (2–4 zones) with troilite and sometimes as clear taenite with kamacite. Zonal taenite contains of type IV plessite and, in rare cases, a core of coarse plessite.

The sulphide composition varies within a narrow range (Table 2). Generally, troilite grains have an irregular or round shape. Some troilite are intergrowths with metal grains following their morphology. The associations have a sharply irregular shape with sinuous edges; both metal and troilite contain many silicate inclusions.

TABLE 1. Electron microprobe analyses (wt%) of silicates in the Galkiv chondrite.

	Olivine		Pyroxene				Feldspatic mesostasis	
			low-Ca		high-Ca		high-Na	high-Ca
	range (107)*	average	range (77)*	average	range (7)*	average	average(2)*	average(5)*
SiO_2	37.3–40.2	38.7	53.7–58.2	55.9	45.9–56.7	52.2	62.3	51.8
Al_2O_3	n.d.–0.10	0.02†	n.d.–1.88	0.30	0.17–13.1	4.17	20.7	31.3
MgO	41.3–44.3	42.7	27.5–34.4	31.0	15.4–26.2	17.9	0.69	0.11
TiO_2	n.d.–0.85	0.06	n.d.–0.57	0.09	n.d.–2.71	0.86	0.75	0.05
CaO	n.d.–0.51	0.02†	0.04–3.22	0.51	5.42–23.2	18.0	3.10	13.6
FeO	16.2–18.4	17.3	5.62–14.1	10.5	1.20–8.40	4.36	1.15	0.63
MnO	0.31–0.51	0.41	n.d.–0.73	0.38	n.d.–0.44	0.27	0.03†	0.03†
Cr_2O_3	n.d.–0.64	0.04	n.d.–1.26	0.31	0.37–2.48	1.22	0.55	0.21
P_2O_5	n.d.–0.25	0.06	n.d.–0.26	0.05	n.d.–0.20	0.10	0.03†	n.d.
V_2O_3	n.d.–0.13	0.01†	n.d.–0.08	0.01†	n.d.–0.07	0.03†	0.02†	0.01†
Na_2O	n.d.–0.08	0.01†	n.d.–0.16	0.02†	n.d.–0.95	0.55	9.47	3.29
K_2O	n.d.–0.04	0.01†	n.d.–0.05	0.01†	n.d.–0.02†	0.01†	0.27	0.07
Total		99.34		99.08		99.67	99.06	101.10
	Fa 17.4–19.5	18.52	Fs 8.34–21.9	15.8	2.09–13.5	7.3	Ab 83.4	30.7
			En 77.1–90.4	83.2	46.8–75.3	53.7	An 15.1	68.8
			Wo 0.08–6.49	1.0	11.2–49.9	39.0	Or 1.53	0.48

*Number in parentheses are the number of analyses that were done.
†Within error limits.
n.d. = not detected.

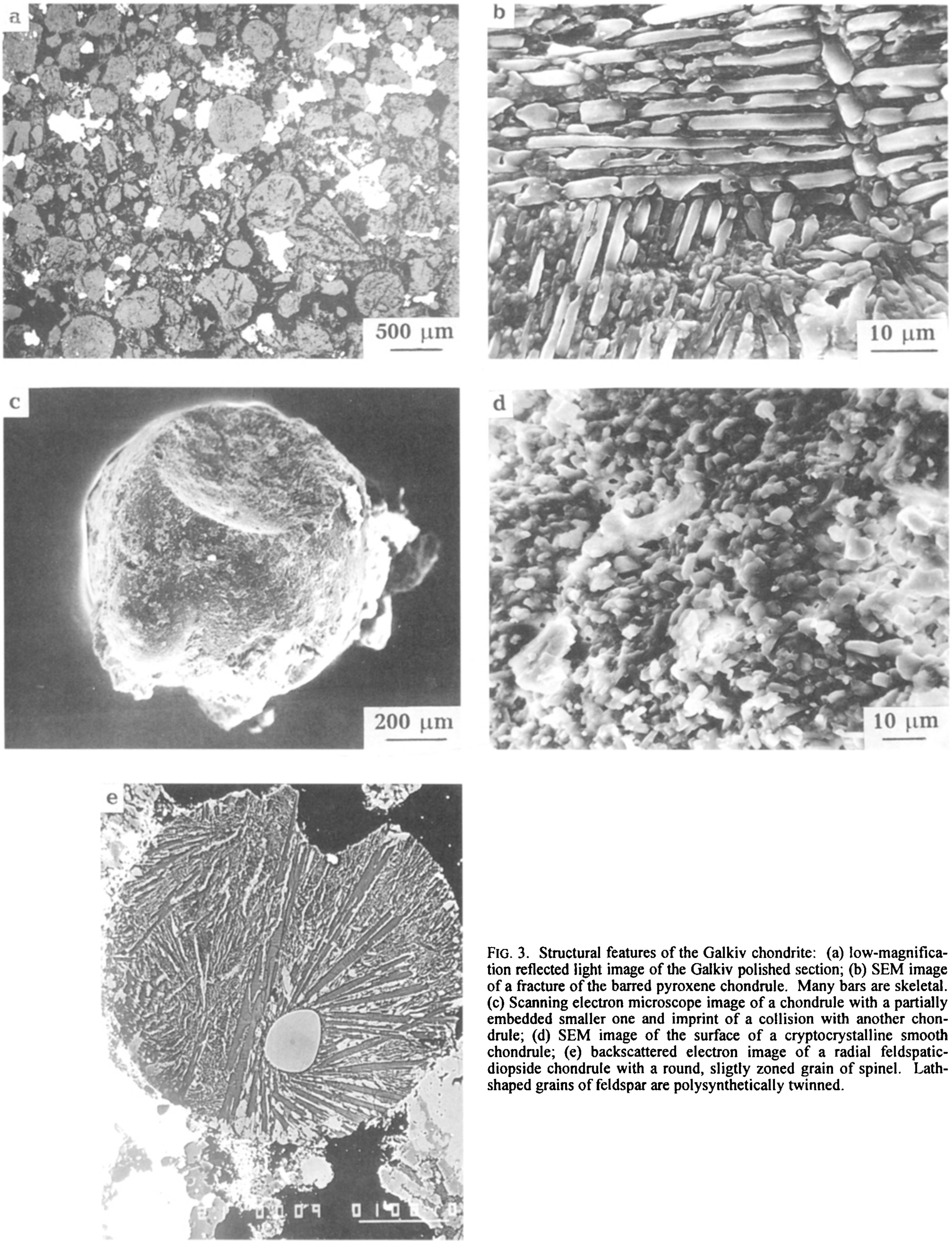

FIG. 3. Structural features of the Galkiv chondrite: (a) low-magnification reflected light image of the Galkiv polished section; (b) SEM image of a fracture of the barred pyroxene chondrule. Many bars are skeletal. (c) Scanning electron microscope image of a chondrule with a partially embedded smaller one and imprint of a collision with another chondrule; (d) SEM image of the surface of a cryptocrystalline smooth chondrule; (e) backscattered electron image of a radial feldspatic-diopside chondrule with a round, sligtly zoned grain of spinel. Lath-shaped grains of feldspar are polysynthetically twinned.

TABLE 2. Electron microprobe analyses (wt%) of metal and troilite in the Galkiv chondrite.

	Kamacite		Taenite		Troilite	
	range (23)*	average	range (19)*	average	range (18)*	average
Cr	n.d.–0.16	0.02†	n.d.–0.16	0.02†	n.d.– 0.03†	0.01†
Fe	91.2–94.6	92.7	49.2–72.2	61.6	61.9–63.6	62.9
Ni	4.45–6.84	5.96	26.0–50.7	36.8	n.d.–0.27	0.04
Si	n.d.–0.07	0.01†	n.d.–0.09	0.01†	n.d.–0.05	0.01†
Cu	n.d.–0.06	0.01†	0.11–0.43	0.21	n.d.–0.48	0.04
Co	0.32–0.58	0.48	0.03†–0.14	0.09	n.d.–0.02†	n.d.
S	n.d.–0.11	0.02†	n.d.–0.06	0.02†	35.7–38.0	36.9
P	n.d.–0.09	0.02†	n.d.–0.09	0.02†	n.d.–0.08	0.02†
Total		99.22		98.77		99.92

*Number in parentheses are the number of analyses that were done.
†Within error limits.
n.d. = not detected.

TABLE 3. Electron microprobe analyses (wt%) of chromite and phosphates in the Galkiv chondrite.

	Chromite		Cl-apatite		Merrillite	
	range (15)*	average	range (10)*	average	range (14)*	average
SiO_2	n.d.–0.27	0.02†	n.d.–0.18	0.05	n.d.–0.21	0.05
Al_2O_3	5.01–5.69	5.34	n.d.–0.05	0.02†	n.d.–0.07	0.02†
MgO	2.28–3.94	2.58	n.d.–0.15	0.03†	2.53–4.17	3.51
TiO_2	1.08–1.63	1.42	n.d.–0.17	0.04	n.d.–0.11	0.02†
CaO	0.01†–0.37	0.06	53.5–57.2	55.3	47.0–49.7	48.1
FeO	27.8–28.9	28.5	0.12–0.46	0.30	0.40–1.55	0.82
MnO	0.61–0.88	0.75	n.d.–0.08	0.02†	n.d.–0.07	0.02†
Cr_2O_3	57.3–60.3	59.3	n.d.–0.13	0.04	n.d.–0.19	0.06
P_2O_5	n.d.–0.20	0.04	37.4–41.3	39.1	41.0–44.3	43.2
V_2O_3	0.51–0.73	0.59	–	–	–	–
Na_2O	n.d.–0.10	0.02†	0.16–0.34	0.24	2.23–3.98	2.72
K_2O	n.d.–0.03	0.01†	n.d.–0.03†	0.01†	0.02†–0.08	0.05
NiO	–	–	n.d.–0.07	0.02†	n.d.–0.10	0.04
S	–	–	n.d.–0.06	0.02†	n.d.–0.04	0.01†
F	–	–	0.23–1.17	0.83	0.25–0.90	0.56
Cl	–	–	2.10–5.51	3.94	n.d.–1.25	0.10
Total		98.63		99.96		99.28

*Number in parentheses are the number of analyses that were done.
†Within error limits.
n.d. = not detected.

Euhedral and anhedral chromite grains (5–30 μm) have a distribution that is typical of chondrites. They contain up to 5.3% Al_2O_3, 2.6% MgO and 1.4% TiO_2 (Table 3). Two compositionally different groups of spinel are present in the chondrite: a low-Cr round slightly zoned grain (80 μm) inside of a radial feldspatic-diopside chondrule (Al_2O_3 = 63.0; MgO = 17.7; FeO = 13.6; Cr_2O_3 = 3.75; V_2O_3 = 0.22; MnO = 0.12; TiO_2 = 0.04; CaO < 0.03; total = 98.46 wt%; number of analyses, n = 1) (Fig. 3e); and high-Cr euhedral zonal crystals (5–50 μm) inside of a porphyritic chondrule (Al_2O_3 = 51.9; MgO = 14.8; FeO = 16.4; Cr_2O_3 = 14.6; V_2O_3 = 0.14; MnO = 0.24; TiO_2 = 0.12; SiO_2 = 0.04; CaO < 0.03; total = 98.25 wt%; n = 2).

Phosphates occur as grains of Cl-apatite or merrilite (Table 3). Both minerals are associated with chromite-silicate-metal intergrowths.

Irregular and prismatic grains (20–50 μm) of quartz were observed in association with pyroxene inside the matrix and inside of granular pyroxene chondrules (SiO_2 = 99.1; FeO = 0.25; P_2O_5 = 0.14; Al_2O_3 = 0.09; Na_2O = 0.05; MgO < 0.03; total = 99.66 wt%; n = 4).

Separate irregular grains of natural Cu (95% Cu) are present inside some of the taenite.

Evidences of Shock Metamorphism

There are many fractures inside silicate, troilite and some phosphate grains. Extinction of silicates varies from sharp to mosaic, but the most widespread are grains with undulatory extinction. A sharp extinction is typical for the grains from porphyritic chondrules. Nearly 25% of the olivine crystals contain planar fractures. The morphology of some parts of small troilite grains testifies to their remelting. Many troilite grains are polycrystalline that suggests shock recrystallization. The presence of a low quantity of coarse plessite in the metal is probably the result of shock reheating.

Weathering

Little Fe staining is visible on the cut surface of the meteorite. In polished sections, rare fine veins of iron hydroxides in silicates are side by side with some metal grains. The absence of oxide rims around the metal and troilite grains indicates that Galkiv, like the more recent ordinary chondrite falls, is weathering stage W0, according to the meteorite weathering scheme of Wlotzka (1993).

CONCLUSIONS

Typical of ordinary chondrites, the chondrule:matrix ratio and the compositions of olivines in Galkiv indicate that the meteorite belongs to the H group of ordinary chondrites. Clearly defined chondrule boundaries, the presence of clinopyroxene, cryptocrystalline glass and rare grains of feldspathic plagioclase indicate a petrological type 4, using the VanSchmus and Wood (1967) classification. Although the PMD of olivine corresponds to a petrological type 5 and PMD of low-Ca pyroxene suggests the chondrite is type 3, we classify Galkiv as an H4 chondrite.

According to the scheme of Stöffler *et al.* (1991), the shock facies is estimated to be S3 (weakly shocked). On the basis of the weathering classification of Wlotzka (1993), the Galkiv chondrite belongs to the stage W0.

The meteorite is a very interesting subject for a further study of its chondrules, which can be easily separated from the matrix, and for its highly porous areas of matrix and inclusions inside of metal and troilite particles.

Acknowledgements–We thank V. B. Sobolev, V. M. Slivinsky for technical assistance, T. N. Gorovenko for help with the preparation of the manuscript and S. Russell for valuable remarks and kind transformation of our Ukranian English to English. D. Schneider and M. Weisberg are thanked for most helpful reviews, which improved the manuscript.

Editorial handling: D. W. G. Sears

REFERENCES

SEMENENKO V. P., GIRICH A. L. AND SHARKIN O. P. (1992a) Highly porous fragments in the Saratov (L4) ordinary chondrite (abstract). *Lunar Planet. Sci.* **23**, 1261–1262.

SEMENENKO V. P., SHARKIN O. P. AND GIRICH A. L. (1992b) Highly porous fragments in the Saratov (L4) chondrite (in Russian). *Geokhimiya* **6**, 881–892.

STÖFFLER D., KEIL K. AND SCOTT E. R. D. (1991) Shock metamorphism of ordinary chondrites. *Geochim. Cosmochim. Acta* **55**, 3845–3867.

VANSCHMUS W. R. AND WOOD J. A. (1967) A chemical-petrologic classification for the chondritic meteorites. *Geochim. Cosmochim. Acta* **31**, 747–765.

WLOTZKA F. (1993) A weathering scale for the ordinary chondrites (abstract). *Meteoritics* **28**, 460.