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THE BAGNONE METEORITE

Abstract — The finding of the Bagnone meteorite, a medium octahedrite weighting about 48 kg, is signaled. After a brief description of the main macroscopic and microscopic features of the Bagnone meteorite, the chemical, microhardeness, density and X-ray data are reported.

INTRODUCTION

During the 1967 summertime prof. STEFANO BONATTI got to know of an unidentified metallic body belonging to noble Noceti family, which is resident in Bagnone (Massa, Italy). STEFANO BONATTI paying a visit to Noceti family, could ascertain that the unknown thing was a big iron meteorite fragment.

On the ground of the gathered news it has not ben possible to ascertain when this meteorite fell, however it seems certain that it was found, on a hill near Bagnone, at the beginning of the present century (very likely in 1904 or 1905). From the finding till the 1967 summertime the meteorite belonged to Noceti family and afterwards it was bought by the Institute of Mineralogy and Petrography of the University of Pisa where the Bagnone meteorite is at present.

STEFANO BONATTI's sudden and unforseen death, happened on the 23rd of April 1968, caused the stopping of the researches that He was carrying out on the Bagnone meteorite. These researches have been taken again and continued by us and therefore only now it is possible to publish the first data about the Bagnone meteorite.

This paper has been written to point out the finding of the Bagnone meteorite. Above all, however, we want to honour the me-

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mory of our loved and unforgettable Master, prof. STEFANO BONATTI, and to remember Him in His last scientific research to which He devoted Himself entirely.

MACROSCOPIC FEATURES

The Bagnone meteorite has a roughly ovoidal shape, with its maximum diameter of about 40 cm and the smallest one of about 18 cm (Fig. 1). It weights about 48 kg.

Its surface is gently undulated and shows many round shaped small protuberances and cavities (one of which is about 3 cm deep)

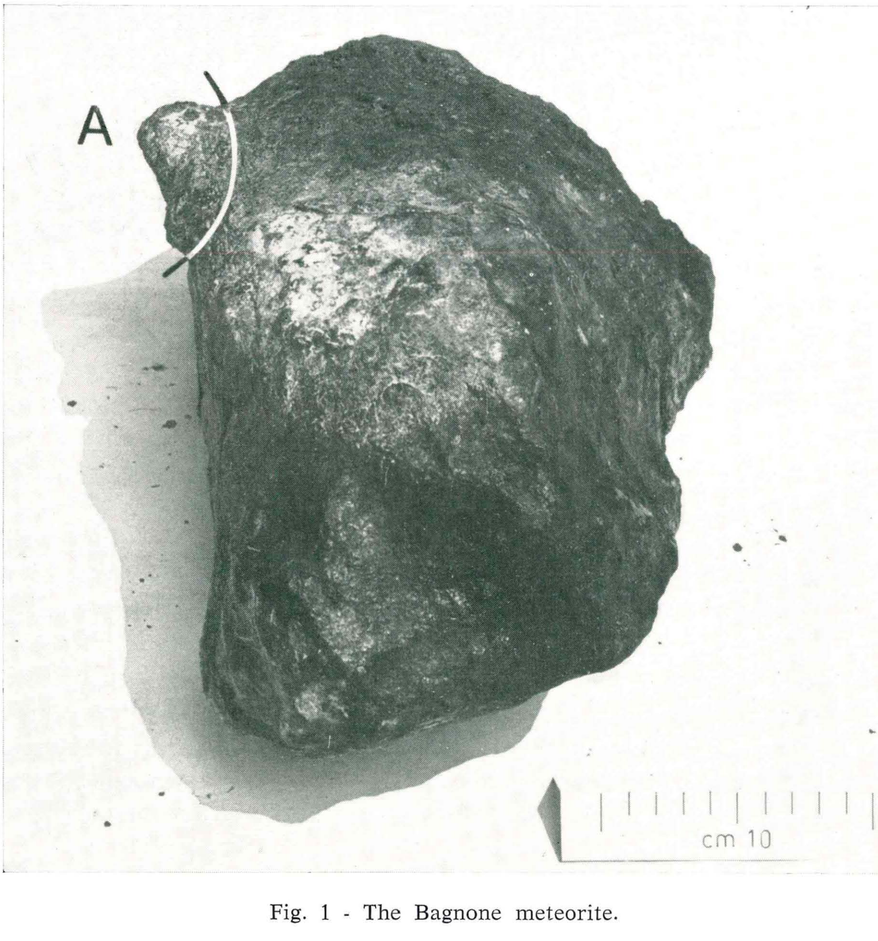


Fig. 1 - The Bagnone meteorite.

that suggest shaping by ablation during the passage through the Earth's atmosphere.

An almost flat surface (visible in the left side of Fig. 1) bounds the meteorite on one side being parallel to the greatest axis of the ovaloid. This flat surface suggests that the Bagnone meteorite may be a fragment of a greater body. The surface features of the Bagnone meteorite are masked by a thick weathering crust, which is particularly developped on the supposed cleavage plane, and therefore it is difficult to study them.

To carry out the chemical and mineralogical study of the meteorite a small fragment, weigthing about 100 gr (labelled A in the potograph, Fig. 1) has been cut by a milling machine equipped with a vidia cutting tool. The chips obtained during the cutting, accurately cleaned at the binocular microscope, have been utilized for the chemical analysis. The small fragment has been utilized for the mineralogical study.

The flat surface of the detached fragment has been polished and macroetched thus obtaining the Widmanstatten pattern typical of a medium octahedrite being the band width of kamacite of about 1-1.5 mm (Fig. 2).

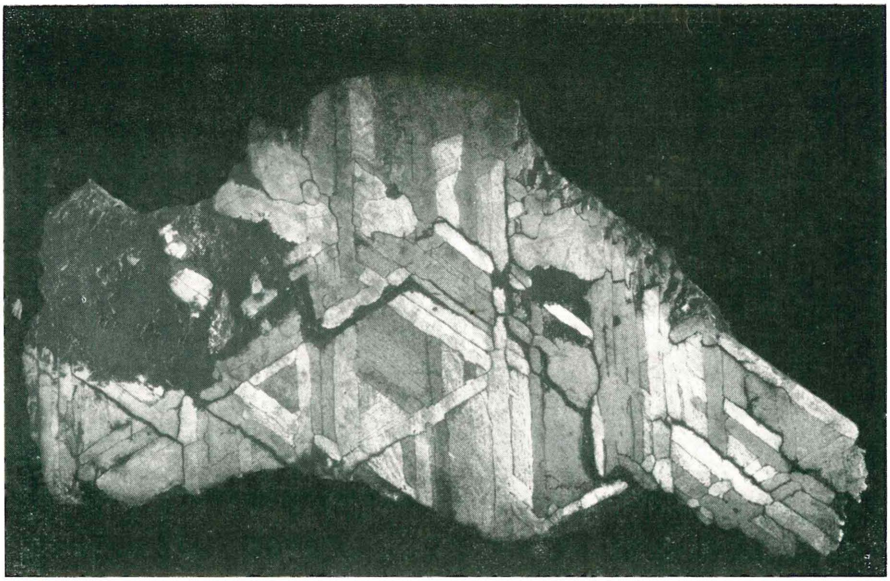
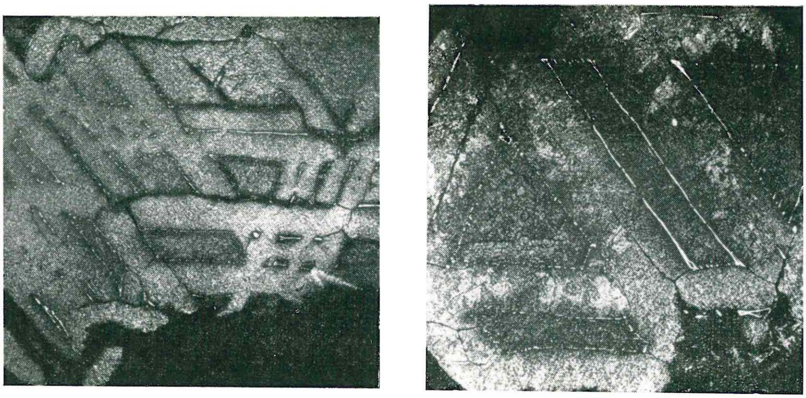


Fig. 2 - Polished and etched surface of a fragment of the Bagnone meteorite.

After the macroetching the surface of the fragment has been lightly polished thus putting in evidence the thin lamellae of taenite which look white in the photograph (Fig. 3 a and b).



a *b*

Fig. 3 *a* and *b* - Particulars of Fig. 2. White lamellae are taenite. Dimensions are 16 mm (a) and 10 mm (b).

Microscopic examination

To study the microscopic features of the Bagnone meteorite the same flat surface of Fig. 2, has been carefully polished and lightly etched with 5% picral for about 5 sec.

At the microscope it has been possible to identify kamacite, taenite, plessite, schreibersite and troilite.

The main features about the relative distribution of kamacite and taenite are schematically represented in Fig. 4. We can note that in the Bagnone meteorite there are pure kamacite bands, with a width of about 1-1,5 mm, bordered by thin taenite lamellae, as well as larger fields of kamacite containing a great deal of very thin taenite lamellae distributed very thickly and parallel to octahedral planes (lamellar plessite).

By means of linear integration over the whole surface of the specimen, the taenite content of the Bagnone meteorite has been measured as equal to 1.73% by volume. In the field labelled E in Fig. 4, by the same technique, it has ben measured 2.31% by volume of taenite. Also these two figures are quite similar, they may be regarded as significantly different.

The schreibersite is present as rhabdites as well as very thin lamellae in kamacite. The rhabdite plates are unevenly distributed

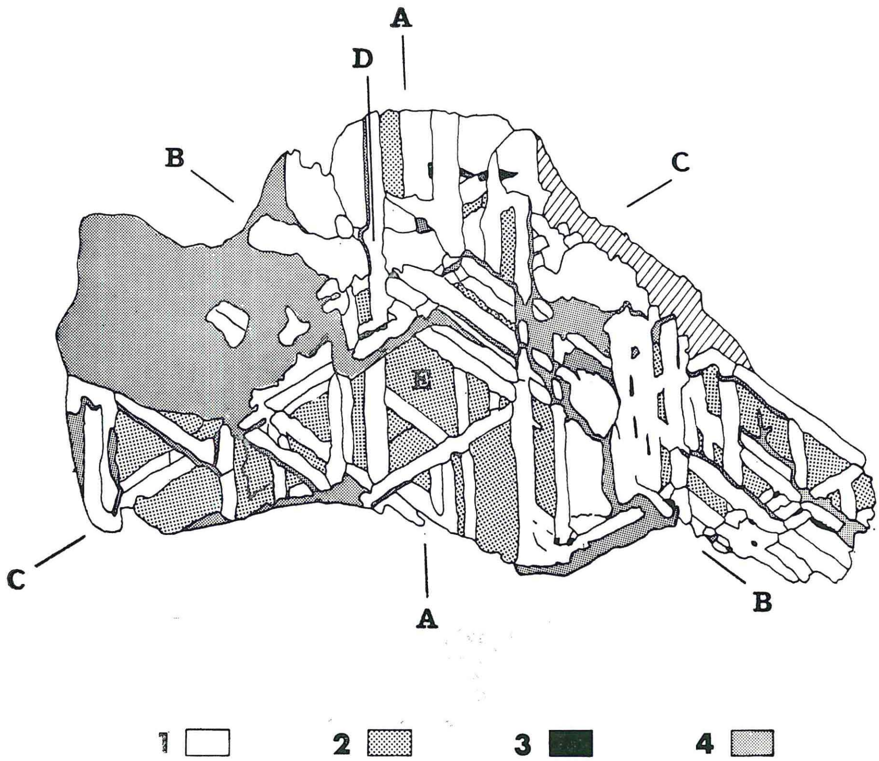


Fig. 4 - Distribution of kamacite, taenite and oxides. 1 - pure kamacite. 2 - kamacite fields containing many very thin lamellae and flakes of taenite (Lamellar plessite).3 - Plessite. 4 - oxides.

through the meteorite and have dimensions comprised between 12 μ and minus than 1.5 μ (Figs 5 and 6).

Troilite has been identified as myrmekitic inclusions in kamacite.

Density

Two densities have been measured on two polished slices one of which of appoximate dimensions 24 x 11 x 3 mm and the other 12 x 20 x 2 mm.

Fig. 5 - Rhadbites. Nital 15 sec. The scale is in μ.

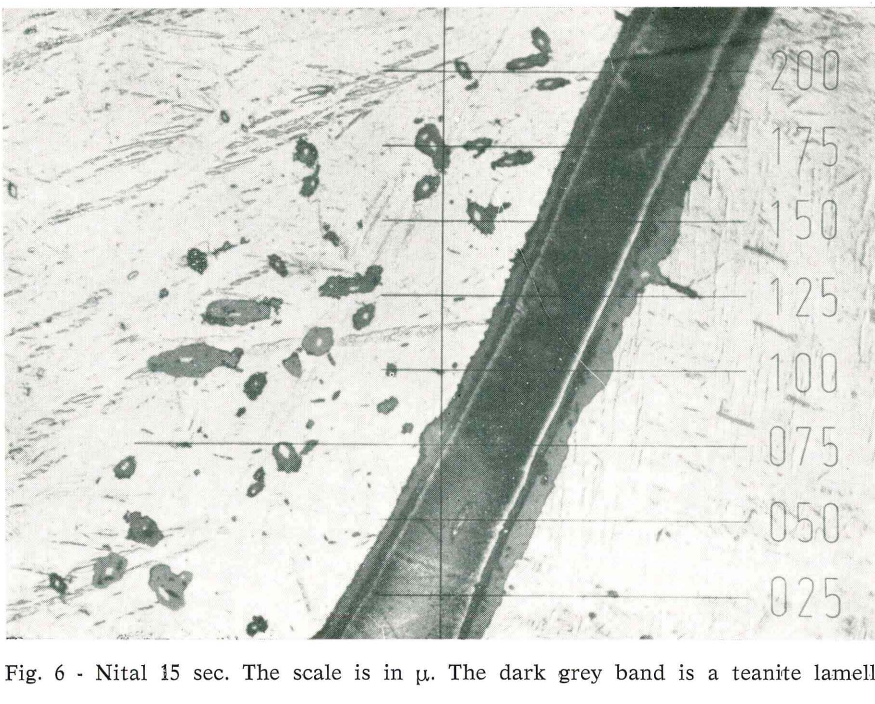


Fig. 6 - Nital 15 sec. The scale is in μ. The dark grey band is a teanite lamella

The greatest slice contained 1.35% by volume of oxides as measured by linear integration at the reflecting microscope, and gave a measured density of 7.841. This value, corrected for the oxides (taken density 4) gave the final value of 7.892. The smallest slice with a measured density of 7.900, did not show at the microscope any trace of oxides. The two values measured independently are in good agreement each other being the estimated measure error equal to 0.01. Therefore we think that the Bagnone meteorite has a density equal to 7.90 $\pm$ 0.01.

Chemical composition

Two partial chemical analyses (Table 1, R. Mazzuoli analyst) have been carried out utilizing the chips obtained during the cutting (analysis n. 1), and the small fragment on which a density equal to 7.900 has been measured (analysis n. 2).

Table 1

	1	2
Fe	81.82	92.86
Ni	7.76	8.46
Co	0.42	0.54
P	0.34	0.34
	90.34	102.21

Analysis number one suggests that the utilized chips, although cleand at the binocular microscope, were not free from weathering products. Therefore we can assume that the Bagnone meteorite contains 8.46% Ni. This value is in good agreement with the features of the Widmanstatten pattern. It seems however somewhat high when compared with the X-ray determined Ni content of the kamacite and with the results of the modal analysis.

Hardeness

Before carrying out the microhardness measurements, the orientation of the flat surface of the examined specimen has been checked against the orientation of the Widmanstatten octahedral pattern. For this aim the angles betwen lines A, B and C (Fig. 4) have been measured and plotted in stereographic projection. From this plot, assuming that the centre of the stereogram represents the pole of the specimen surface we have identified the poles of the octahedral planes (dots in Fig. 7). All the interesting angular values are reported in Fig. 7. It is to be noted that the flat surface of the specimen is inclined about 13.5° on an octahedral plane.

After a careful calibration of the microhardness tester, the

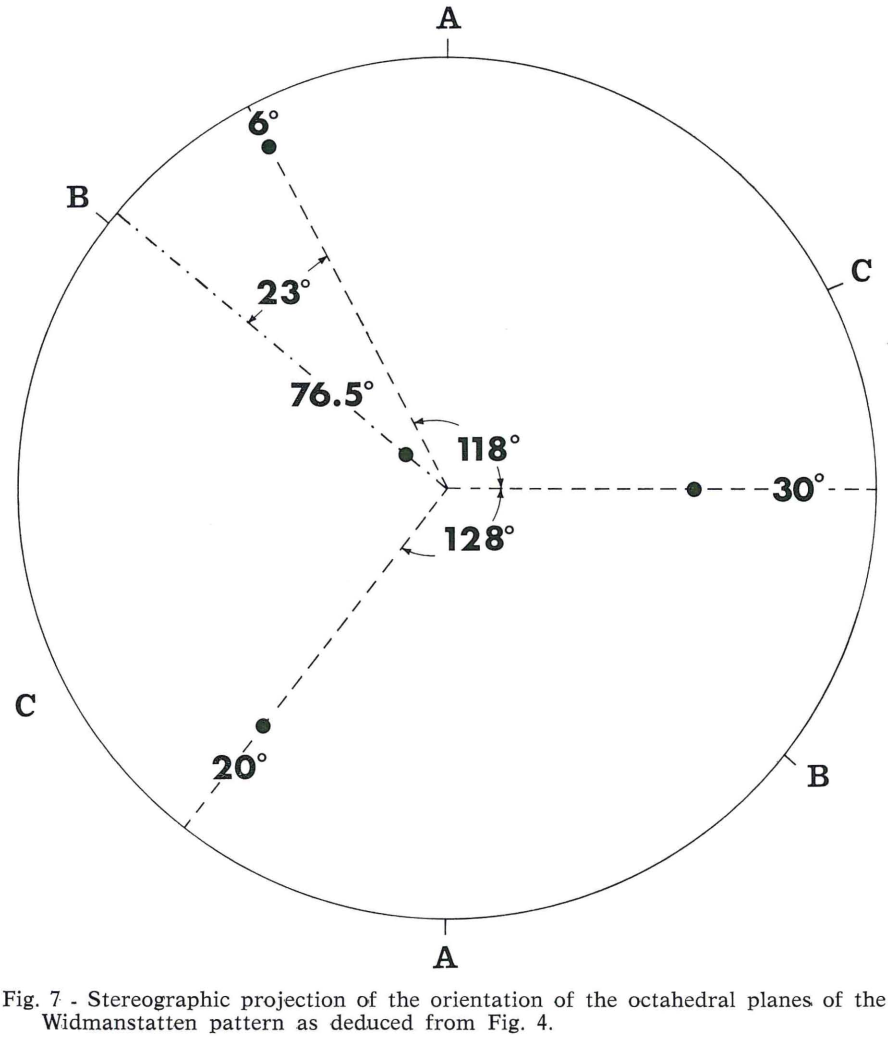


Fig. 7 - Stereographic projection of the orientation of the octahedral planes of the Widmanstatten pattern as deduced from Fig. 4.

measures reported in Table 2 have ben carried out on kamacite along the line labelled D in Fig. 4. The mean measured hardness of taenite is $Knoop_{100}$ = 346.

TABLE 2

Distances from the border of the specimen	HV_{100}	$Knoop_{100}$ the greatest diagonal of the indentation mark is parallel to			
		A	A	B	C
35 μ	327				
110	345				
125		337		379	395
180	337				
200			337		
250	348				
330	362				
520		364		387	386
550			403		
600	340				
1 mm		374	380	355	413
1.5	354				
2		373	385		401
3	320				
4		398	423		
8		369			
15			395		
mean value	342	369	394	374	399

mean $Knoop_{100}$ = 384

X - RAYS

Ror the X-ray analyses a powder specimen has been prepared by a prolonged grinding, in a ball mill, of some very small fragments of the Bagnone meteorite mixed with an equal amount of powdered metallic silicon. The added silicon has greatly enhanced the grinding action of the ball mill.

After an hour of grinding a very thin powder has been obtained. At this stage however a x-ray powder pattern (diffractometer, Fe radiation) showed only the silicon peaks and some very broadened kamacite reflections. The powder was therefore annealed at 380°

TABLE 3

Before annealing

Rad.		2 θ Measured	2 θ Corrected	hkl	d(Å)	*a*
Fe Kβ	kamacite	51.27	51.30	110	2.0295	2.8701
Fe Kβ	Si	54.41	54.442			
Fe Kα	kamacite	56.98	57.01	110	2.0295	2.8701
Fe $K\alpha_1$	Si	60.52	60.55			
Fe $K\alpha_1$	Si	101.89	101.97			
Fe Kα	kamacite	111.48	111.55	211	1.1715	2.8696
Fe Kβ	Si	114.28	114.35			

After annealing at 380° for 10 hours

Rad.		2 θ Measured	2 θ Corrected	hkl	d(Å)	*a*
Fe Kβ	Si	54.425	54.442			
Fe Kα	taenite	55.69	55.71	111	2.0735	3.5914
Fe $K\alpha_1$	kamacite	56.98	57.00	110	2.0285	2.8687
Fe $K\alpha_1$	Si	60.53	60.55			
Fe $K\alpha_1$	Si	101.89	101.966			
Fe $K\alpha_1$	kamacite	111.43	111.50	211	1.1711	2.8686
Fe $K\alpha_2$	kamacite	111.76	111.83	211	1.1712	2.8688
Fe $K\alpha_1$	Si	121.61	121.670			

TABLE 4

d_{obs}	I	
4.20	m	goethite
3.37	d	goethite
2.96	m	magnetite
2.69	m	goethite
2.52	f	magnetite
2.46	m	goethite
2.25	d	goethite
2.18	d	goethite
2.09	m	magnetite and goethite
1.92	d	goethite
1.805	d	goethite
1.715	m	magnetite and goethite
1.614	mf	magnetite and goethite
1.565	d	goethite
1.510	d	goethite
1.480	mf	magnetite and goethite

for 10 hours. After annealing the X-ray powder pattern showed silicon, magnetite and haematite peaks as well as very well defined peaks of kamacite and one taenite peak. The intensities of the (111) peak of taenite and (110) peak of kamacite are in the ratio of about 4 : 100.

Table 3 reports some measures before and after annealing and the computed values of the *a* parameter. From this data the analysed kamacite would contain about 6% of Ni.

The X-ray powder pattern of the weathering crust is reported in Table 4.

(*ms. pres. il 15 gennaio 1970; ult. bozze il 20 maggio 1970*).