References and Notes

1. D. Virgo and S. S. Hafner, *Mineral. Soc. Amer. Spec. Pap. 2* (1969), p. 67.
2. S. S. Hafner and D. Virgo, Proceedings of the Apollo 11 Lunar Science Conference, *Geochim. Cosmochim. Acta* (Suppl. 1, vol. 3) 2183 (1970).
3. S. K. Saxena and S. Ghose, *Amer. Mineral.* **56**, 532 (1971).
4. E. C. T. Chao, *Science* **156**, 192 (1967); Proceedings of the Apollo 11 Lunar Science Conference, *Geochim. Cosmochim. Acta* (Suppl. 1, vol. 1) (1970); B. M. French and N. M. Short, Eds., *Shock Metamorphism of Natural Materials* (Mono, Baltimore, 1968).
5. P. S. DeCarli, in *Shock Metamorphism of Natural Materials*, B. M. French and N. M. Short, Eds. (Mono, Baltimore, 1968), p. 129.
6. R. W. Dundon and L. S. Walter, *Earth Planet. Sci. Lett.* **2**, 372 (1967); unpublished work.
7. S. S. Pollack and P. S. DeCarli, *Science* **165**, 591 (1969).
8. The line widths of Fe^{2+} in tektite glasses were found to be two or three times as large as those in crystalline materials of comparable chemical composition [J. G. Marzolf, J. T. Dehn, J. F. Salmon, *Advan. Chem. Ser.* **68**, 61 (1968)].
9. S. S. Pollack, unpublished semiannual NASA grant report (Nov. 1969).

10. We thank Dr. S. S. Pollack, Mellon Institute, Pittsburgh, for the materials. Work supported by NSF grant GA-14811 and NASA grant NAS9-8080 (to S.S.H.).

9 July 1971; revised 7 September 1971

Chondrules: First Occurrence in an Iron Meteorite

Abstract. *Complete chondrules and fragments of chondrules have been found within silicate inclusions from the octahedrite iron meteorite Netschaevo. The bulk chemical composition, mineralogy, and mineral chemistry indicate that this chondritic material has properties intermediate between those of the H-group chondrites and those of the enstatite chondrites.*

In an extensive study (*1*) of the group of iron meteorites that contain major silicate inclusions (*2*), Bunch *et al.* reported finding a chondrule in an inclusion from the octahedrite Netschaevo. We here confirm this finding and report the presence of additional chondrules in this meteorite (*3*). A chemical analysis was performed on a small amount of this rare material (*4*), and a more extensive examination of this meteorite was undertaken.

Figures 1 to 3 show three chondrules that appear in the two small polished thin sections that were prepared. In addition, three other less well defined, fragmented chondrules were observed. The petrographic texture of the matrix is similar to that of the equilibrated H-group chondrites with more total metal plus sulfide than is usually seen in H-group specimens.

The phases actually observed within the silicate inclusions are the following: bronzite (85 mole percent enstatite), calcic pyroxene (89 percent diopside), olivine (86 percent forsterite), plagioclase (82 percent albite, 14 percent anorthite, 4 percent orthoclase), chromite, whitlockite, chlorapatite, metal, troilite, and schreibersite. Microprobe analyses (*1*) demonstrated that the individual silicate phases are homogeneous within grains and from grain to grain.

The chondrules represent several of the types seen in ordinary chondrites (H-, L-, and LL-chondrites). Figure 1 shows one chondrule consisting of so-called "bars" of olivine rimmed with an optically continuous overgrowth of olivine. The apparent dark bands between the bars are mostly olivine at optical extinction. Some of the dark blebs are troilite, but no metal was found within it. The large opaque grain that interrupts the chondrule rim is metal, with pyroxene attached to it. A segment of a chondrule of radiating pyroxene blades is shown in Fig. 2. The dark layers are pyroxene at optical extinction. Specks of both troilite and metal are found within this chondrule. Figure 3 shows an unusual chondrule which consists of approximately equal amounts of olivine and pyroxene in a complex interlocking system of blebs. The opaque minerals in this chondrule are primarily troilite with some chromite. No glass was observed in any of the chondrules that we examined.

Table 1. Weight percentages derived from a chemical analysis of a silicate inclusion from the Netschaevo meteorite as compared with data for average H-group and average L-group chondrites.

Component	Netschaevo meteorite*	Average H-group chondrite (*5*)	Average L-group chondrite (*5*)
Fe	24.77	17.23	7.70
Ni	2.50	1.58	1.12
Co	0.10	0.08	0.06
FeS	3.70	5.35	6.17
SiO_2	32.37	36.52	39.88
TiO_2	0.21	0.13	0.15
Al_2O_3	1.82	2.43	2.31
Cr_2O_3	0.59	0.36	0.44
FeO	8.82	8.87	13.12
MnO	0.35	0.25	0.27
MgO	19.65	23.48	24.89
CaO	1.64	1.82	1.90
Na_2O	0.76	0.85	0.88
K_2O	0.19	0.14	0.14
P_2O_5	0.54	0.23	0.26
H_2O^+	0.2	0.33	0.34
H_2O^-	0.77		
C	0.21	0.10	0.09
Total	99.19	99.75	99.72

* E. Jarosewich, analyst.

The chemical analysis of a silicate inclusion from the Netschaevo meteorite (Table 1) appears somewhat anomalous when contrasted with analyses of average H- and L-group chondrites. The total amounts of iron and nickel are higher, and the amount of FeS is lower, than that of either chondrite type. Superficially the sample appears to be "more H" than the normal H-group chondrite, trending toward intermediacy between the H-group and the enstatite chondrites. Moreover, the compositions of the pyroxene (85 percent enstatite) and olivine (86 percent forsterite) are slightly beyond the most magnesian end of the range of compositions observed in the H-group chondrites, namely, 84 percent forsterite and 85 percent enstatite (*5*).

Although samples of the Netschaevo meteorite have been heated in attempts to utilize the metal (*6*), the textures and the homogeneous silicate compositions were unaffected by the short-duration heating. Heating effects are restricted to the partial oxidation of some of the small metal grains within the silicate inclusions. Some of the metal grains are deeply rusted. The major portion of metal, surrounding the silicate inclusions, in contrast to the small metal grains within the inclusions, is less affected by heating because of its coarse grain size and low ratio of surface area to mass. In the analysis any ferric oxide present is reported as the metal because it is clearly due to the oxidation of iron. Furthermore, all nickel is traditionally reported as the metal. The analytical weight ratio of (Ni + Co) to (Ni + Co + Fe) is 9.5 percent, which is in good agreement with the value for the ratio in the surrounding metal, 9.8 percent, reported in the literature (*7*).

The mole ratio of MgO to (MgO + FeO) for the whole analysis is 0.80. Because orthopyroxene and olivine comprise the major ferromagnesian silicate phases, their ratio, 0.85 to 0.86, should be that of the bulk meteorite. Only rarely have values in perfect agreement been obtained for this ratio,

Table 2. Weight percentages (Table 1) recalculated to a metal-free, sulfide-free, and water-free basis; Fo_{85} (last column), 85 mole percent forsterite.

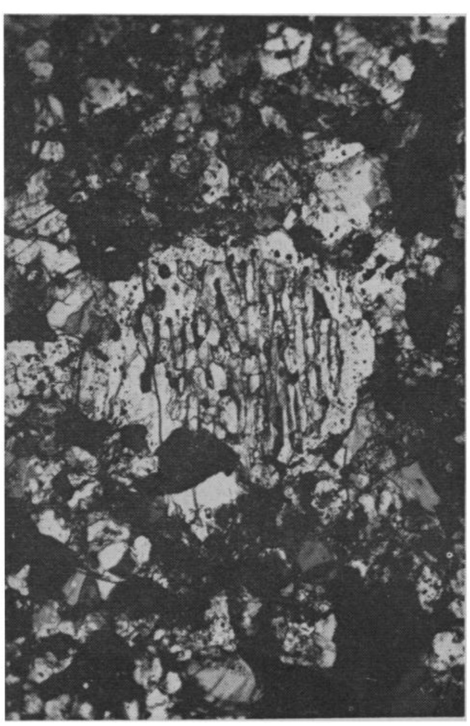
Component	Netschaevo meteorite	Average H-group chondrite (*5*)	Average L-group chondrite (*5*)	Weekeroo Station + 50% Fo_{85} (*4*)
SiO_2	48.21	48.59	47.25	47.41
TiO_2	0.31	0.17	0.18	0.14
Al_2O_3	2.71	3.24	2.74	2.62
Cr_2O_3	0.88	0.48	0.52	1.38
FeO	13.13	11.81	15.55	12.98
MnO	0.52	0.33	0.32	0.30
MgO	29.27	31.24	29.59	31.03
CaO	2.44	2.42	2.25	2.59
Na_2O	1.13	1.13	1.04	0.90
K_2O	0.28	0.19	0.17	0.10
P_2O_5	0.80	0.31	0.31	0.05
C	0.31	0.10	0.09	0.49

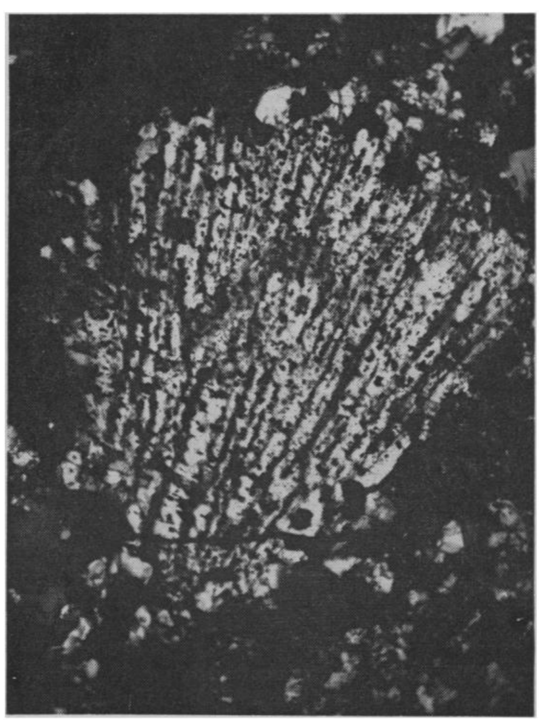
Table 3. Mode (in percent by volume) calculated from data derived from an analysis performed on a metal-free, sulfide-free, and water-free basis (Table 2). The compositions of several phases are given as determined by microprobe analysis (*1*). The mode is calculated in terms of phases actually observed except for the exclusion of very minor amounts of chlorapatite and the inclusion of all carbon as graphite (which was not observed).

Phase	Formula	Percentage
Bronzite	$Mg_{0.85}Fe_{0.15}SiO_3$	52.0
Olivine	$Mg_{1.72}Fe_{0.28}SiO_4$	26.0
Calcic pyroxene	$Ca_{0.91}Mg_{0.98}Fe_{0.11}Si_2O_6$	5.4
Plagioclase	$Na_{0.78}Ca_{0.16}K_{0.06}Al_{1.16}Si_{2.84}O_8$	13.6
Chromite	$Fe_{0.79}Mg_{0.21}Al_{0.5}Cr_{1.5}O_4$	0.9
Whitlockite	$Ca_{2.7}Mg_{0.3}P_2O_8$	1.6
Graphite	C	0.5

as discussed by Keil (*5*). In this case, the disagreement may indicate that some ferrous iron may be attributable to heating and weathering effects. There is no way to assess this amount quantitatively.

The chemical analysis, when recalculated on a metal-free, sulfide-free, and water-free basis (Table 2), is quite similar to that of an average H-group chondrite, with only some subtle differences such as the following: the amounts of chrominum, carbon, phosphorus, and titanium are somewhat higher, and the amount of magnesium is somewhat lower. The latter result reflects the greater abundance of pyroxene over olivine in contrast to the situation in ordinary chondrites. The calculated mode (Table 3) gives twice as much pyroxene as olivine. Microprobe analyses (*1*) and optical point counting ($n = 320$) of the two small polished thin sections bear out this reversed abundance. The ratio of olivine to (olivine + pyroxene) from the calculated mode is 0.31. Modal calculations were performed on analyses of 16 H-group and 15 L-group chondrites. This ratio, for the H-group chondrites, ranges from 0.43 to 0.67, with an average value of 0.54, whereas for the L-group chondrites the range is 0.46 to





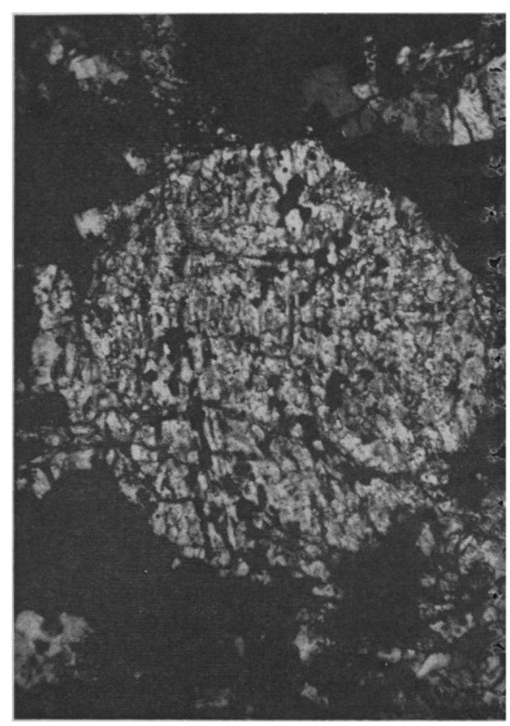


Fig. 1 (left). Barred olivine chondrule in a silicate inclusion from the Netschaevo meteorite. Chondrule diameter = 0.50 mm. (Crossed Nicol prisms.) Fig. 2 (middle). Segment of a chondrule of radiating pyroxene blades in a silicate inclusion from the Netschaevo meteorite. Long dimension = 1.00 mm. (Crossed Nicol prisms.) Fig. 3 (right). Blebby olivine and pyroxene chondrule in a silicate inclusion from the Netschaevo meteorite. Chondrule diameter = 0.81 mm. (Crossed Nicol prisms.)

0.81, averaging 0.62. Earlier work on the iron meteorites with silicate inclusions has indicated that pyroxene is usually more abundant than olivine. For example, in the cases of the Campo del Cielo and Woodbine meteorites, the calculated modal ratio of olivine to (olivine + pyroxene) is 0.41 in each case, and for the Weekeroo Station meteorite the ratio is zero.

In summary, the chondritic silicate masses in the Netschaevo octahedrite appear to represent a chemical and mineralogical transition from the characteristics of the equilibrated H-group chondrites toward those of the enstatite chondrites. The Netschaevo chondritic silicate masses are characterized by the following composition: (i) the amount of pyroxene is greater than the amount of olivine; (ii) the ratio of MgO to (MgO + FeO) for both pyroxene and olivine is at or above the upper extremum value for the H-group chondrites; (iii) the total content of metal plus sulfide (31 percent by weight) is higher than that of ordinary chondrites (15 to 25 percent) and tends toward the content in enstatite (*5*) chondrites (average, 50 percent); and (iv) the carbon content is three times higher than that of ordinary chondrites and approaches values observed in the enstatite chondrites. The Netschaevo meteorite must represent a lower oxidation state than that of an H-group chondrite and may represent a somewhat higher equilibration temperature. Bunch *et al.* (*1*) calculated an equilibrium temperature of 870° to 890°C. An approximate equilibrium temperature of 900°C or more is indicated by the method of Olsen and Bunch (*8*). These temperatures are slightly higher than those estimated by Van Schmus and Koffman (*9*) for the ordinary chondrites but are close to the value obtained more recently by Williams (*10*).

The mechanism and meaning of chondrule formation and preservation are still matters of lively discussion, as is the exact relation of iron to chondritic meteorites, or the relation of iron meteorites with silicate inclusions to all other types of meteorites. Within the group of iron meteorites with silicate inclusions the silicate masses have varied bulk compositions and textures (*1*, *4*, *11*). Olsen and Jarosewich (*4*) have suggested an olivine fractionation relationship from a chondritic parent composition that would approximately account for the unusual chemistry of the silicate inclusions in an iron meteorite like Weekeroo Station. In fact, the addition of about 50 modal percent olivine (85 percent forsterite) to the analysis values for the Weekeroo Station meteorite would yield a bulk analysis closely similar to that of the Netschaevo meteorite (Table 2). The presence of chondrules in the silicate inclusions of the Netschaevo meteorite may serve to connect the several diverse major groups of meteorites.

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References and Notes

1. T. E. Bunch, K. Keil, E. Olsen, *Contrib. Mineral. Petrol.* **25**, 297 (1970).
2. A distinct group, not to be confused with pallasites or mesosiderites. See (*1*) for description.
3. Field Museum of Natural History specimen Me 1154.
4. E. Olsen and E. Jarosewich, *Earth Planet. Sci. Lett.* **8**, 261 (1970). The analytical method used is described in this reference.
5. K. Keil, *Handbook of Geochemistry: Meteorite Composition* (Springer-Verlag, Berlin, 1969), vol. 1, chap. 4, pp. 78–115.
6. M. Hey, *Catalogue of Meteorites* (British Museum of Natural History Publication 464, London, ed. 3, 1966).
7. C. Rammelsberg, *Monatsber. Deut. Akad. Wiss. Berlin* **1870**, 444 (1870).
8. E. Olsen and T. Bunch, *Amer. Mineral.* **55**, 1829 (1970).
9. W. R. Van Schmus and D. M. Koffman, *Science* **155**, 1009 (1967).
10. R. J. Williams, *Geochim. Cosmochim. Acta* **35**, 407 (1971).
11. B. Mason, *Mineral. Mag.* **36**, 120 (1967).
12. We thank Dr. J. Wasson, University of California, Los Angeles, for suggesting that we examine this problem, and G. Moreland, U.S. National Museum, for preparing the polished thin sections. One of us (E.O.) was supported by NASA grant NGR-14-052-001.

1 July 1971

Inorganic Particles in Cigars and Cigar Smoke

Abstract. *A number of crystalline and optically isotopic inorganic materials are used in the manufacture of reconstituted tobacco sheets. These sheets, used primarily in inexpensive cigars, often contain diatomaceous earth, which exists in part in the silica mineral form cristobalite, a known fibrogen. Diatom fragments with this crystalline form have been observed in the main smoke stream of cigars made with these tobacco sheets.*

Many cigars today, generally those which retail at less than 30 cents each, are made up in part of reconstituted tobacco, commonly called tobacco sheets. The use of this material has increased since its introduction in the United States in 1954. It may be manufactured by one of several processes and may contain additives, up to 40 percent, including much inorganic particulate matter (*1*). Patents for tobacco sheets used exclusively to make cigars indicate that bentonite, heat-treated montmorillonite, acid-treated clays, glass fibers, and diatomaceous earth may be used in its manufacture (*2*, *3*).

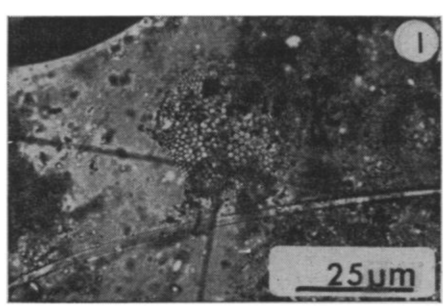

Fig. 1. Diatom body and ceramic fiber from ashed, reconstituted tobacco sheet seen between crossed Nicols with polarized light optics. The birefringent background material is made up in part of natural contaminants, including clays, oxalate crystals, and quartz grains.

Diatomaceous earth, although predominantly opal (amorphous hydrated silica), is occasionally partially crystalline, commonly in the form of the known fibrogens (*4*) tridymite and cristobalite (*5*). Lenses of well-crystallized cristobalite occur commonly in commercially worked deposits of diatomaceous earth (*5*). Industrially calcined diatomaceous earth, containing much cristobalite, may produce significant disease (diatomaceous earth pneumoconiosis) when inhaled (*6*). Less is known about the disease potential of fibrous glass materials, which vary chemically, structurally, and morphologically.

Tobacco sheet was introduced into the cigar industry primarily for economic purposes, to decrease tobacco loss by utilization of fines generated during manufacture and to decrease unit cost by introduction of more automation. However, cigar tobacco sheet patents claim that the additives also form strong