EL QUEMADO, A NEW TYPE OF STONE METEORITE FALLEN NEAR ACAPULCO; A PRELIMINARY REPORT

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RESUMEN

Se da una breve descripción del análisis químico de una muestra del meteorito *El Quemado*. Se trata de un espécimen altamente recristalizado, que no coincide con ninguno de los grupos bien conocidos; es intermedio entre los grupos de condritas E y H, mostrando similitudes con algunas incrustaciones de silicato en los meteoritos ferrosos.

ABSTRACT

A short description with chemical microprobe analyses is given of the *El Quemado* meteorite. It is a highly recrystallized specimen which matches none of the well-known groups; intermediate between the E and H group chondrites, it shows also similarities with some silicate inclusions in iron meteorites.

Key words: **METEORS AND METEORITES.**

I. INTRODUCTION

A 20 g. sample of the stone of *El Quemado*, a 1.9 kg meteorite fallen in August 1976, has been kindly given to us by the Museum of the Institute of Geology of the National University of Mexico, to be investigated at the University Pierre et Marie Curie, in Paris. This stone has been recovered 15 minutes after its fall at 2.8 km of that locality by 99°53' long. W, 16°53' lat. N. The event has been recorded in *SEAN Bull.* 3 No. 1 and a short description given by Dr. G. S. Rubio.

II. PETROGRAPHY

It is thoroughly recrystallized and we have not seen any relict chondrules. The structure is granoblastic, as noted by G. Rubio, the ferromagnesian silicate crystals are polygones limited by flat faces (Fig. 1, Plate 3) with frequent 120° triple junctions between grains. Besides olivines and orthopyroxenes, green clinopyroxenes are easily visible with a hand lens; these are xenomorphic towards the first ones (Fig. 2, Plate 3) as are the plagioclase feldspars (Fig. 3, Plate 3), the phosphate (mainly chlorapatite), the chromite, iron-nickel and troilite.

Many orthopyroxene crystals have a core enriched in a multitude of iron-nickel blebs as shown in Figures 4 and 5, (Plate 4). On a fractured surface, one can see these numerous globules (mostly FeNi, also some FeS) that may have come through the pyroxene, full of apparently square-limited holes presumably indicating the (110) ($\overline{1}10$) crystallographic planes. On a polished section, the orientation of the metal grains in the pyroxene host is clearly visible. This may be interpreted as follows: either equilibrating to a new physico-chemical environment, the crystals were corroded and acted as a sieve through which metal and sulfide migrated, or, coprecipitated early phases were dissolved leaving empty

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voids; these phases could be related to feldspathic glass, usually present as tiny grains inside or between chondritic pyroxenes. The feldspar is now represented by large (200 μm) polysynthetically twinned oligoclase crystals, and by a few rounded grains included in the other silicates.

III. MINERAL CHEMISTRY

Electron microprobe investigations were carried out with a CAMECA MS46 model. In all cases, except for feldspar, the beam size was no more than 1 μm. We used an accelerating voltage of 15 kV, specimen current 30 nA for the silicates, and 20 kV, 50 nA for oxide and metal. The corrections were made using the EMPADR VII program. Marjalahti olivine and Johnstown hypersthene were used as standards along with terrestrial minerals. The composition of representative ferromagnesian minerals are reported in Table 1.

a) *Olivine:* the fayalite content varies between Fa 10 and Fa 12.5. Some crystals are slightly zoned with a little more magnesian core: the difference does not exceed 1% Fa. The CaO content is low, consistent

with a recrystallization history. On a plot of mole % fayalite versus mole % ferrosilite, the olivine analyses fall into line with olivine of most pallasites (Busek 1977) in a position intermediate between ordinary chondritic material and silicates of iron meteorites.

b) *Pyroxenes:* orthopyroxenes varies from 11 to 13% Fs, with no more than 2% Wo. The core, rich in iron-nickel globules, has the same iron-magnesian ratio as the rim. The green chromian diopside, with 51-55% En, 4.2-5% Fs, 40.5-43.5% Wo, growing in large crystals, may be considered in equilibrium with orthopyroxene and olivine.

The Mg—Fe distribution coefficient

$$K_D = (Fe/Mg)^{cpx} / (Fe/mg)^{opx} = 0.66$$

corresponds to a last equilibrium temperature in the range 800-900°C (Kretz 1963; Navrotsky 1978). The Ca/Ca + Mg ratios of clinopyroxenes show a temperature range from 980 to 1030°C, which may be slightly lowered because of the presence of ferrosilite molecule (from data of Boyd and Schairer 1964). The Cr_2O_3 partitioning between the two pyroxenes is similar to that of silicate inclusions in iron meteorites (Bunch and Olsen 1975).

c) *Chromite:* the chromites are homogeneous from grain to grain but, compared to data from Bunch and Keil (1971), their chemical composition is unlike that of any known meteorite group: they are closer to pallasite chromites but for their TiO_2 and MnO content, similar to those of silicate inclusions in iron.

The distribution of Fe^{2+} and Mg between olivine and chromite is complicated by the presence of other cations in the chromite structure. Using Jackson (1969) equations.

$$K_D = (Fe^{2+}/Mg)^{chr} / (Fe/Mg)^{oll} = 13,40$$

and

$$T = \frac{5\,580\alpha + 1\,018\beta - 1\,720\delta + 2\,400}{0.90\alpha + 2.56\beta - 3.08\delta - 1.47 + 1.987\,L_n\,K_D}$$

with $\alpha =$ Cr/Cr + Al + Fe^{3+}, $\beta =$ Al/Cr + Al + Fe^{3+}, $\delta = Fe^{3+}$/Cr + Al + Fe^{3+}, we find an equilibrium temperature of 1270°C ± 150°, well in the range of those observed for silicate inclusions in iron meteorites (Bunch *et al.* 1970) and pallasites (Bunch and Keil

TABLE 1

COMPOSITION OF REPRESENTATIVE FERROMAGNESIAN MINERALS

	Olivine	Ortho-pyroxene	Clino-pyroxene	Chromite *
SiO_2	40.36	55.34	52.50	.....
Al_2O_3	.....	0.30	0.82	5.79
Cr_2O_3	0.02	0.27	1.08	60.02
TiO_2	0.01	0.21	0.49	1.17
FeO	11.11	8.05	3.23	21.90
MgO	48.53	33.59	20.44	6.19
CaO	0.02	0.96	21.18	.....
MnO	0.56	0.62	0.37	2.71
Na_2O	.....	.....	0.11	.....
Σ	100.61	99.34	100.22	98.31

*Σ = 98,31 with 0.53 V_2O_3
olivine Fo 88, Fa 12 ; orthopyroxene En 86, Fs 12, Wo 2, clinopyroxene En 54, Fs 5, Wo 41 ;

chromite $(Fe_{4,75}\ Mg_{2,60}\ Mn_{0,65})\ (Cr_{13,36}\ Al_{1,92}\ V_{0,12}$

$Fe_{0,40}^{3+})\ O_{32}$.

1971). Note however that this calculation disregards the effect of Ti and Mn ions, the uncertainty thus introduced being difficult to evaluate. Taking into account this additional uncertainty, the temperature value given by the chromite-olivine geothermometer does not necessarily conflict with the lower one given by the pyroxene-pyroxene geothermometer, which moreover, may be a lower limit according to Olsen and Bunch (1975) analysis following Blander's (1972) model.

d) *Feldspar:* the oligoclase feldspar has a mean composition of $An_{13}Ab_{83}Or_4$ with little variation from grain to grain.

e) *Kamacite, taenite and troilite:* The metal distribution is rather non uniform on a scale of a few mm. The metal and sulfide content does not seem, at a first glance, to differ markedly from that of the H group chondrites but final assessment of this point must await the results of a bulk chemical analysis. However, the relations between kamacite and taenite as revealed by a short etching are quite particular and distinct from those generally observed in H chondrites: their interlocking grains look like a puzzle.

The kamacite is 5 to 6% Ni rich with 0.90 to 0.98% Co and around 0.1% P. The core of the zoned taenites and of the martensites are quite low in nickel, rejoining kamacite composition at 6-8% Ni while the maximum nickel (measured over spots 1 μm in diameter) in the rim of a 170 × 350 μm crystal is 33.6% Ni (and 0.54 Co). Taenite also occurs as zoned rings or bands within the kamacite (Figure 6, Plate 4) with typically 10-12% Ni in the center of the bands, 25% Ni on the rim. Some large kamacite grains are polycrystalline; that could be explained by the fact that they have been reheated into the taenite field (Wood 1967) above 800°C. The occurrence of 0.1 P in the kamacite is also a thermal indicator as is possibly the low Ni content of taenite and martensite cores. On the other hand, the absence of detectable Ni in troilite (in which Co is present) points to a slow cooling, at least at low temperature (350°C).

IV. CONCLUSIONS

This short mineralogical study of the *El Quemado* stone reveals a number of outstanding pecularities.

All the characteristics of the minerals point to a high temperature recrystallization history.

As no shock deformations are visible in any crystals (apart from some cracks), if ever a shock had existed —a plausible event to explain, beside recrystallization, the obliteration of the chondritic structure— high temperature annealing would have erased them.

If a chondrite, we may compare it to Kakangari —an unequilibrated chondrite intermediate between the E and H group (Graham and Hutchison 1974) and to Netschaevo —an equilibrated chondrite close to the H group, consisting of angular masses set in a metallic matrix (Olsen and Jarosewitch 1971; Bild and Wasson 1977). It would be then a specimen of the rare petrological type 7 (Dodd *et al.* 1975). If not, it may be compared to mesosiderite such as Enon, the mineral phases of which are very similar (Bunch *et al.* 1970). But, as far as we know, no metallic mass has been found in connection with *El Quemado*. A final classification must await further major and trace-element analyses. Also, as shown by Clayton and Mayeda (1978) and Srinivasan and Anders (1977) oxygen isotope studies and trapped noble gas determinations may help to trace back genetic relationships with other well established meteorite types.

The finding of a new meteorite with chemical and petrological parameters distinct from those of the well-defined meteorite groups emphasizes the fact, already illustrated by the Netschaevo and Kakangari meteorites, that the source region of meteorites has a greater diversity than heretofore recognized. This great diversity is indeed also reflected by the presence, in brecciated meteorites, of a wider range of rock types than represented by known macroscopic meteorites, as evidenced by recent isotopic studies (Clayton and Mayeda 1978). Meteorite parent-bodies have indeed sampled along the time a far richer collection of primitive solar system material than does the earth to-day, as meteoritic matter striking the earth comes from a limited number of parent-bodies from which it originates through a limited number of collisions. The finding of exotic objects such as *El Quemado* brings forward fresh information regarding the conditions prevailing in the early solar system which apparently resulted in the formation of a rather continuous chemical sequence of primitive matter.

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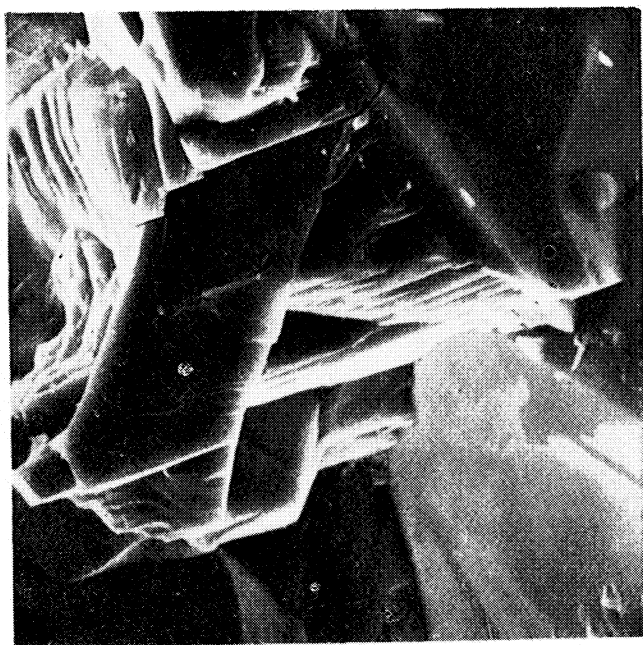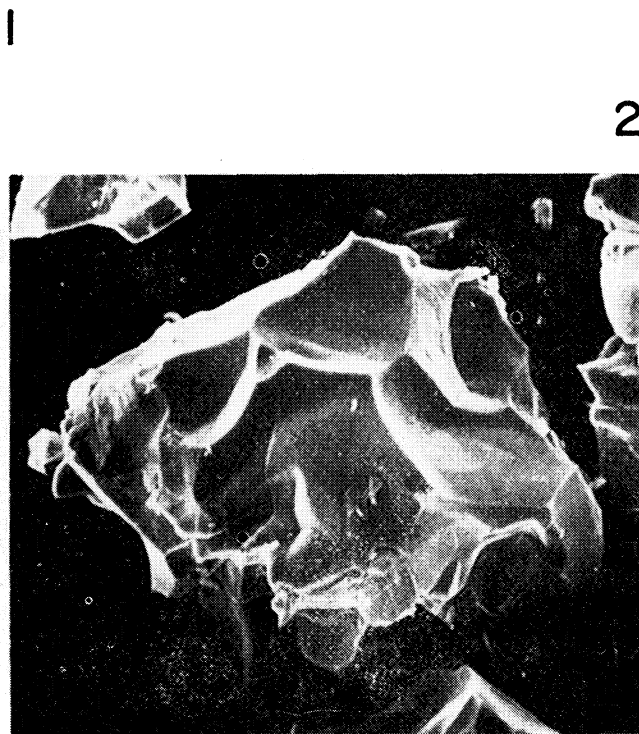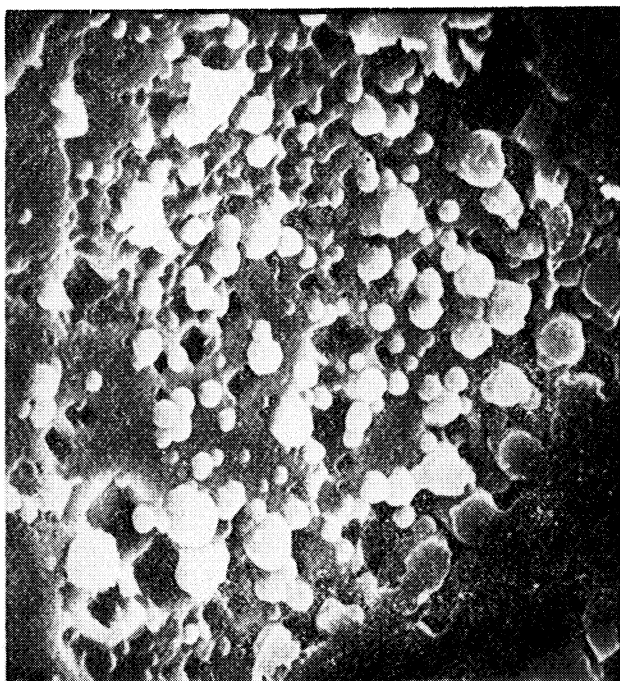Wood, J. A. 1967, *Icarus*, **6**, 1.

PLATE 3

Fig. 1. Morphological features of olivine crystals × 300. On the left side, the crystals were in contact with other minerals; on the right side, we can notice many facets of a free developed surface.

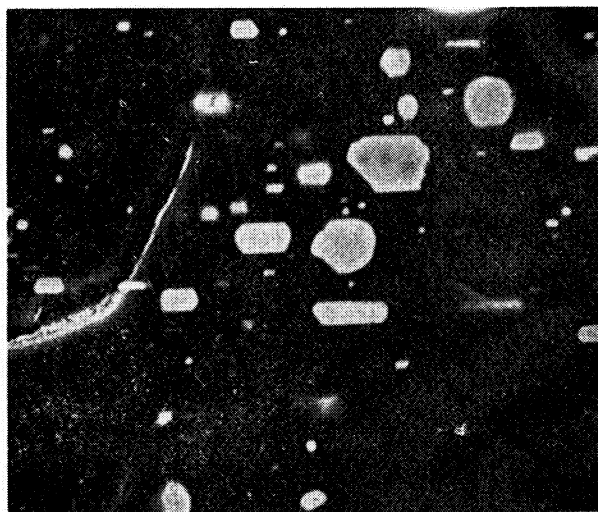Fig. 2. A large xenomorphic crystal of chromian diopside × 250.

Fig. 3. A polysynthetically twinned plagioclase feldspar × 900.

PLATE 4

FIG. 4. Iron-nickel blebs in the core of an orthopyroxene crystal. Nearly square holes are visible; on the left corners, the pyroxene rim is compact × 3 000.

FIG. 5. On a polished section, the nickel-iron inclusions show a parallel orientation × 2 000.

FIG. 6. After etching, zoned taenite bands appear in that kamacite area, looking somewhat like a Widmannstätten pattern. The contours of the bands have been underlined because of insufficient contrast of the pictures × 300.

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