SEM STUDIES OF WHITLOCKITE AND CHROMITE IN METAL-SULFIDE DROPLETS IN A C3 ALLAN HILLS METEORITE AND THEIR IMPLICATIONS. Eun-Hee Cirlin. Rockwell International Science Center, Thousand Oaks, CA 91360.

The meteorite ALHA 77003 is classified as type C3(1) and was referred to as type CO3(2). In this study whitlockite and chromite were found in metallic droplets in both chondrules and in matrix of polished section 77003,78 and were studied with a scanning electron microscope. Our SEM is equipped with a Princeton Gamma Tech x-ray analyzer, which is interfaced with a Kevex 7000 data analysis system. The quantitative analyses with standards using the program MAGIC V give better than 2% accuracy for major elements and satisfactory results for minor elements.

Recently Rambaldi et al (3) reported finding whitlockite in unequilibriated ordinary chondrites for the first time. They found the whitlockite in the interfaces between Si, Cr-rich kamacite and sulfides. In the present SEM studies, the whitlockite was found in all three phases, kamacite, taenite and troilite of metal-sulfide droplets in both chondrules and matrix. Many whitlockite worm-like grains were present along the edges of the metallic droplets (Fig. 1a). Troilite was present either as a shell around the metal (Fig. 1a), or with sharp crystal boundary lines (Fig. 1c). Also other small inclusions ($< 3\ \mu m$) of chromite and Fe-rich olivine were present in the metal (Fig. 1b and 1c). Table 1 shows analysis of typical whitlockite.

It was suggested for Apollo 14 samples that whitlockite was formed as a result of a reaction of schreibersite with surrounding pyroxene and oxygen (4). Our SEM studies showed that Ca in chondrule pyroxene, next to the whitlockite tooth in troilite is indeed depleted (Fig. 1d), suggesting that a similar reaction occurred in the meteorite. Since phosphorous has little solubility in sulfides (5), it must have been in the metal before the whitlockite grains were formed by oxidation. Then the metal was partially sulfurized some time later. Therefore, finding of similar whitlockite grains in both metal and troilite imply that the troilite formed from metal in a later stage after the whitlockite grains were formed and therefore after the chondrules were formed. Theoretical calculations by Olsen and Fuchs (6) supported by experimental work of Friel and Goldstein (7) can be used to show that in the solar nebular condensation process, the whitlockite would have formed at less than 680°K, whereas the troilite would be formed at around 700°K. This suggests that the troilite in ALHA 77003 was not formed during the solar nebular condensation sequence but was probably formed at a later time in a planetesimal (8).

The conclusion from the present study of this unequilibriated meteorite is that the troilite in chondrules resulted from sulfurization which occurred after the chondrules formed. This is in strong contrast to the conventional interpretation (9, page 179).

Table 1. Energy Dispersive X-ray Analysis of a Whitlockite

Element	Na	Mg	Si	P	Ca	Fe	Total
No. of cations in formula based on 8 oxygens	0.44	0.32	0.11	1.91	2.16	0.31	5.25

(1) Marvin U. B. and Mason B. (1982) Catalog of Meteorites from Victoria Land, Antarctica, 1978-1980, p. 85. (2) Swart P. K., Grady M. M., Norris S. J., Wright I. P. and Pillinger C. T. (1983) Lunar and Planetary Science XIV, p. 763. (3) Rambaldi E. R. and Rajan R. S. (1982) Meteoritics 17, p. 271. (4) El Goresy A., Taylor L. A. and Ramdohr P. (1972) Proc. Lunar Sci. Conf. 3rd, p. 333. (6) Olsen E. and Fuchs L. H. (1967) Icarus 6, p. 242. (5) Keil K. (1968) J. Geophys. Res., 73, p. 6945. (7) Friel J. J. and Goldstein J. I. (1976) Proc. Lunar Sci. Conf. 7th, p. 791. (8) Armstrong J. T., Meeker G. P., Huneke J. C. and Wasserburg G. J. (1982) Geochimica et Cosmochimica Acta, 46, p. 575. (9) Dodd R. T. (1981) Meteor-

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ites: A Petrologic-Chemical Synthesis, Cambridge University press.

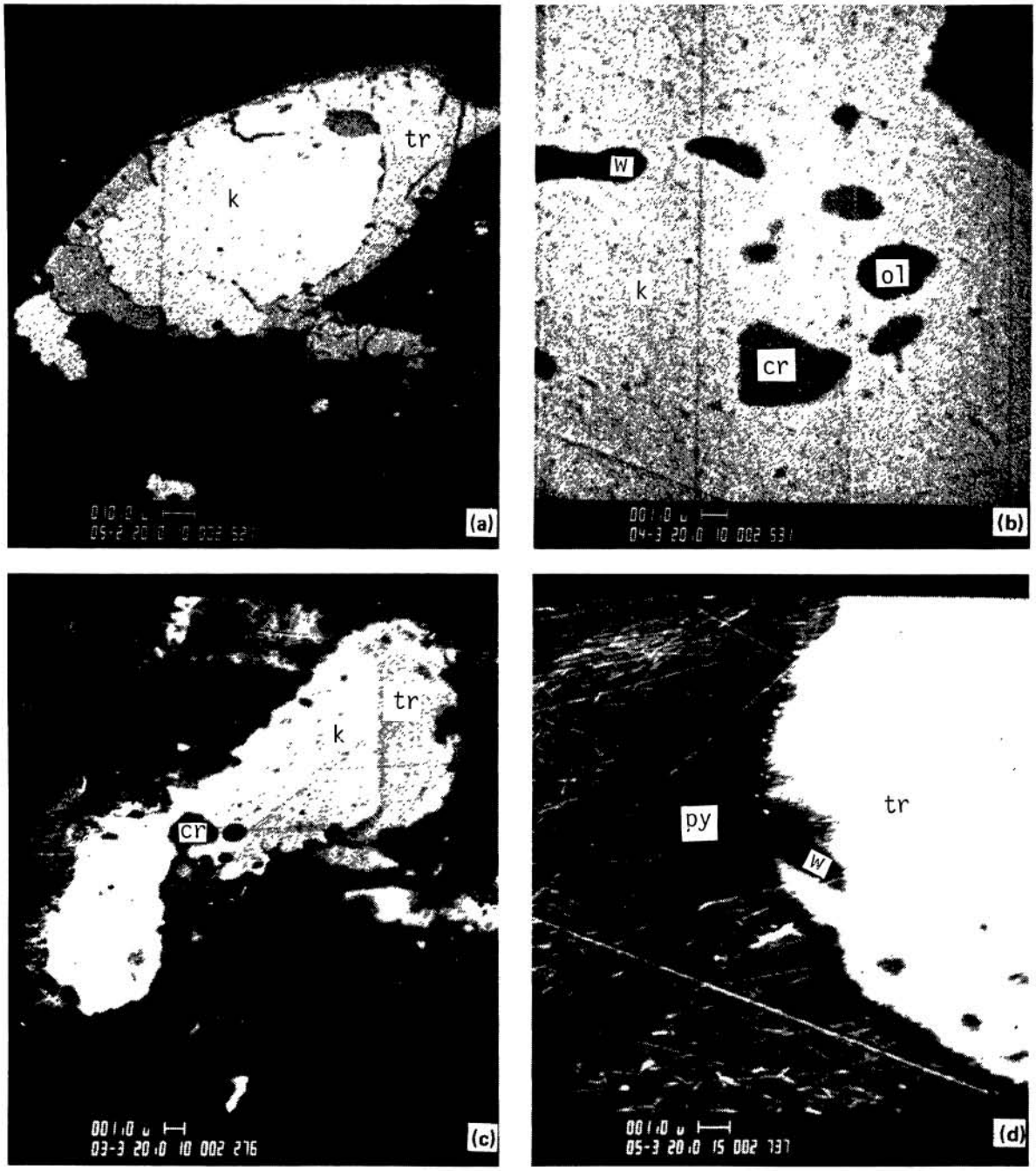

Fig. 1a. Backscattered electron image (BSE) of a metal droplet showing troilite shell around kamacite. Dark worm-like whitlockite grains are present in both kamacite and troilite along the edge of the droplet (b) BSE of small inclusions such as chromite and Fe-rich olivine present in kamacite (c) SEM photo of a metal droplet with chromite and whitlockite grains. Note a sharp boundary between kamacite and troilite (d) A whitlockite tooth in troilite. Ca in chondrule pyroxene near the whitlockite tooth is very depleted, suggesting that Ca from surrounding pyroxene reacted with phosphorous from the metal phase-forming whitlockite.