DISCOVERY OF COESITE AND SIGNIFICANCE OF HIGH PRESSURE PHASES IN THE GUJBA CB CHONDRITE. M. K. Weisberg[1,2], M. Kimura[3], A. Suzuki[4], E. Ohtani[4] and N. Sugiura[5] [1]Department of Physical Sciences, Kingsborough College And Graduate Center of the City University of New York, Brooklyn, NY 11235, [2]Department of Earth and Planetary Sciences, American Museum of Natural History, New York, NY10024, USA, mweisberg@kbcc.cuny.edu. [3]Faculty of Science, Ibaraki University, Mito 310-8512, Japan, [4]Institute of Mineralogy, Petrology and Economic Geology, Tohoku University, Sendai 980-8578, Japan, [5]Department of Earth and Planetary Science, Univ. of Tokyo, Japan

Introduction: Deciphering the origin and thermal histories of chondrules, metal and other components in chondrites is essential to our understanding of the early solar system. The unusual characteristics of the CB chondrites have generated considerable interest and disagreement over the origin and significance of their components. Their unusual characteristics [1] include: (1) high metal abundances (60-80 vol.% metal), (2) most chondrules have cryptocrystalline or barred textures, (3) moderately volatile lithophile elements are highly depleted and (4) nitrogen is enriched in the heavy isotope. CB chondrites have been interpreted to be primitive nebular materials containing metal that condensed directly from the nascent nebular gas [1-6]. Others have contended that they formed in a vapor cloud produced during an impact event [7, 8]. Recent Pb^{207}-Pb^{206} dating of chondrules in the Gujba CB_a chondrite show formation ages younger than chondrules in other chondrites, which is more consistent with impact models for formation of the chondrules in the CB_a chondrites [9, 10]. However, the CB chondrite parent body experienced an extensive post accretion shock history that has obscured some of its primary character.

Using a combination of petrology and Raman Spectroscopy we have been studying high-pressure phases in the Gujba CB chondrite. We previously reported our finding of majorite and wadsleyite in Gujba [11] and here we report preliminary results of our discovery of the high-pressure silica polymorph coesite. Our goal is to constrain the thermal - shock history of the CB chondrites and their parent body.

Results: Petrology - The Gujba CB_a chondrite consists of large round and irregular-shaped metal, chondrules and chondrule fragments, surrounded by finer-grained brecciated areas interspersed with melt. Its petrographic characteristics are fairly typical of CB_a chondrites [1], with the exception of containing some chondrules that are complete spheres. This is in contrast to the other CB_a chondrites (Bencubbin and Weatherford) in which most chondrules are fragmental and highly deformed. Metal chondrules (spheres) in Gujba are up to ~1cm in size and the largest silicate chondrule is about 1.5 x 1cm and is cryptocrystalline in texture. Interstitial to the large metal and silicate chondrules are smaller mm-sized silicate chondrule fragments that are texturally and compositionally similar to the larger ones. Most silicate chondrules and fragments are barred olivine in texture, some are cryptocrystalline, and barred pyroxene has also been reported [12]. Barred chondrules consist of olivine bars with low-Ca pyroxene and/or Ca-pyroxene and interstitial feldspathic glass.

We studied areas that are interstitial to the large metal and silicate chondrules in Gujba (Fig. 1). The areas consist of small (10µm to 1mm) barred olivine fragments, surrounded by a fine (sub-micrometer) matrix. The matrix is dominated by two silicate phases and dotted with tiny (2-30µm-size) blebs of FeNi metal. Metal also occurs as vein-like structures and at boundaries between fragments and the matrix, suggesting that it was heated and remobilized.

One area studied contains a relatively large (2 mm) barred olivine fragment that consists of olivine ($Fa_{1.7}$), Mg-Al spinel and a glassy mesostasis with fine crystals of Ca-pyroxene. In this fragment, the bars have bends suggesting that they have been plastically deformed. In addition, the olivine bars are heavily fractured and faulted, displaced along fractures [11]. A thin vein of metal and silicate, impact-melt material, runs down the center of the inclusions leading to a pocket of fine metal and silicate within the fragment.

Raman Spectroscopy - We collected Raman Spectra from points in fragments and matrix in the areas described above. The Raman spectra show that the barred fragments and matrix in these regions have various combinations of olivine and low-Ca pyroxene, as well as majorite garnet ($Mg_4Si_4O_{12}$), a phase that forms by high-pressure transformation of low-Ca pyroxene and wadsleyite, a high-pressure product of olivine. Compositions of the majorite suggest that it is a majorite - pyrope solid solution. More recently we discovered the presence of grossular-pyrope in two small fragments in the matrix and two areas that contain coesite. The coesite occurs in clusters that are about 7-10 µm in size (Fig. 1).

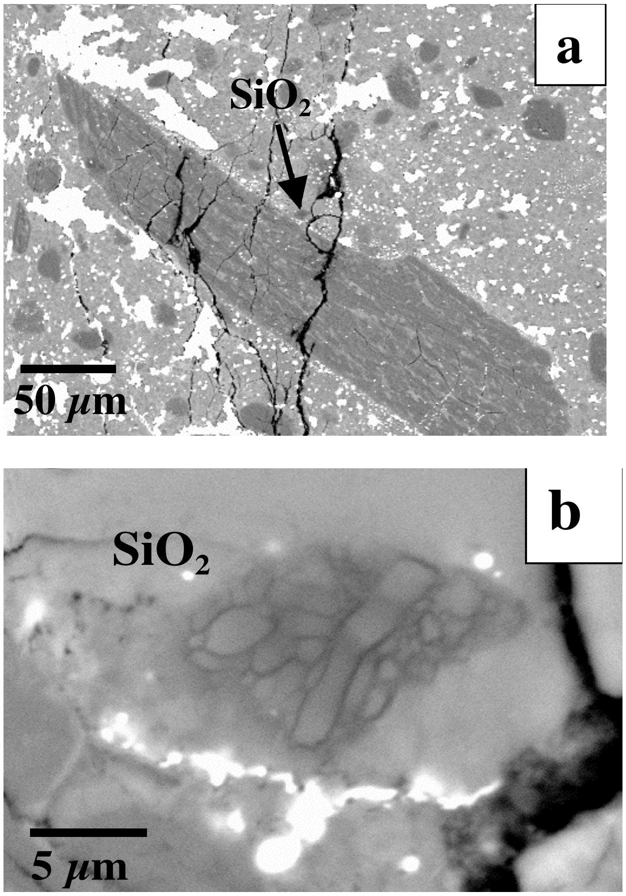

Figure 1. (a) Area in Gujba showing a barred olivine fragment (BO) surrounded by matrix, veins of metal and smaller BO fragments. The arrow shows a small (8μm) cluster of silica. (b) Enlargement of the cluster from 1a, which consists of the high-pressure silica polymorph coesite.

Discussion: We previously reported high-pressure phases majorite-pyrope$_{ss}$ and wadsleyite in the matrix and in barred olivine fragments in the Gujba CB chondrite [11]. This was the first discovery of high-pressure phases in a CB chondrite and in a carbonaceous chondrite. Majorite has been reported in shock veins in ordinary chondrites [e.g., 13-15] and as dendritic crystals intergrown with interstitial glass in the Tenham ordinary chondrite [16]. The only natural occurrence of wadsleyite is in shocked ordinary chondrites [16] and now the Gujba CB chondrite. We now report clusters of coesite and coesite mixed with quartz in the matrix of Gujba. This is the first discovery coesite in a meteorite. Coesite has been found in tektites and heavily shocked rocks from the Ries crater [e.g., 17, 18]. The high-pressure phases observed in Gujba record a range of pressure conditions. Additionally, within Gujba, the occurrence of high-pressure phases is variable from one area to another, on the scale of millimeters or less. These observations may suggest heterogeneous distribution of pressures due to shock.

All CB chondrites contain impact melt areas throughout, suggesting a planetesimal wide collision. Based on the presence of similar impact melt textures in all of the CB chondrites, we predict that high-pressure minerals are present in all of them. The timing of the shock event is not entirely clear and multiple events are possible. The high-pressure phases that we document here record a high temperature – pressure impact event that is superimposed onto, and thus post-dates formation of, the chondrules in the CB chondrites. The origin of the barred chondrules and metal in the CB chondrites remains controversial and cannot be resolved with the data presented here. The barred chondrules and metal in the CB chondrites may be primary materials formed prior to the impact event either generated in an earlier collision or in the nebula. Pb-isotopic ages of 4562.7±0.5 Ma have been reported for Gujba chondrules and 4562.8 Ma for chondrules in the Hammadah al Hamra 237 Cb_b chondrite [9, 10], suggesting that these objects are younger than chondrules in other chondrites and formed after the dissipation of dust in the protoplanetary disk [10]. The young age of the CB chondrite chondrules is consistent with planetesimal scale collision scenarios for the origin of components in the CB chondrites. However, high shock pressures and temperatures, presence of impact melt surrounding and penetrating into chondrules and deformation in chondrules in the CB chondrites suggest that resetting of chondrule ages due to loss of Pb is a possibility and formation ages of the CB chondrules may be difficult to obtain.

References: [1] Weisberg M. K. et al. (2001) *MAPS,* 36, 401-418. [2] Weisberg M. K. et al. (1990) *Meteoritics,* 25, 269-279. [3] Weisberg M. K. and Prinz M. (1999) *30th Sypm. Ant. Met.*, *NIPR*, Japan. [4] Krot A. E. et al. (2002) *MAPS,* 37, 1451-1490. [5] Meibom A. et al. (1999) *JGR*, 104, 22,053-22,059. [6] Campbell A. J. et al. (2001) *GCA*, 65, 163-180. [7] Kallemeyn G. W. et al. (1978) *GCA*, 42, 507-515 [8] Campbell A. J. et al. (2002) *GCA,* 66, 647-660 [9] Amelin Y. and Krot A. E., 2005 *LPS XXXVI,* #1247 [10] Krot A. E. et al. (2005) *Nature* 436, 989-992. [11] Weisberg M. K. and Kimura M. (2004) *LPSC XXXV,* #1599. [12] Rubin A. E. et al. (2001) *LPSC XXXII,* #1779 [13] Smith J. V. and Mason B. (1970) *Science,* 168, 832-833. [14] Chen M. et al. (1996) *Science*, 271, 1570-1573. [15] Kimura M. et al. (2003) *EPS*L, 217, 141-150. [16] Price G. D. et al. (1979) *Contrib. Min. Pet.* 71, 211-218. [17] Stoffler D. (1971) *JGR,* 76, 5474-5488. [18] Stoffler D. and Langenhorst F. (1994) *Meteoritic,s* 29, 155-181.