

**A NEW HIGH-PRESSURE POLYMORPH OF CHLORAPATITE IN THE SHOCKED SIXIANGKOU (L6) CHONDRITE.** M. Chen<sup>1,3</sup>, B. Wopenka<sup>2</sup>, X. Xie<sup>3</sup>, A. El Goresy<sup>1</sup>. <sup>1</sup>Max-Planck-Institut für Kernphysik, D-69029 Heidelberg, Germany; <sup>2</sup>Department of Earth and Planetary Sciences, Washington University St. Louis MO 63130, USA; <sup>3</sup>Guangzhou Institute of Geochemistry, Academia Sinica, 510640 Guangzhou, China.

We report the occurrence of a new high-pressure polymorph of chlorapatite in shock-induced melt veins of the Sixiangkou (L6) chondrite. The new phase has a similar composition as the unshocked apatite. Its Raman spectrum is distinctly different from those of unshocked hexagonal and monoclinic apatites. The new phase coexists with other high-pressure polymorphs i.e. ringwoodite, wadsleyite and majorite.

**Introduction:** Apatite and whitlockite are important minor constituents of ordinary chondrites. Their behavior during shock-wave compression of chondrites is not fully understood. Fuchs reported shock-induced recrystallization of whitlockite in the Farmington (L5) chondrite [1], but high pressure polymorphs have not been reported either from static experiments or from naturally shocked chondrites so far. In heavily shocked L and H chondrites, melt veins are usually barren of any phosphates encountered in the unshocked regions. This, and the presence of high concentrations of P in melted dendrites in such melt veins strongly suggest that phosphate minerals break down at the post-shock peak temperatures and that the released P is reduced to enter the FeNi metal alloy [2]. Here we report the first natural occurrence of a shock-induced high-pressure polymorph of chlorapatite, describe shock features encountered in whitlockite, and present Raman spectra of the shocked and unshocked phases in the Sixiangkou (L6) chondrite.

**Occurrence:** The new polymorph of apatite (phase A) and the shocked whitlockite occur in shock-induced silicate melt veins of the Sixiangkou chondrite. They coexist with high-pressure polymorphs of olivine and pyroxene (ringwoodite, wadsleyite, and majorite), as well as diaplectic plagioclase glass and metal-troilite eutectic intergrowths [3]. Grains of the two shocked phosphate phases range from 6 to 70  $\mu\text{m}$  in diameter. Some grains of phase A are sprinkled with FeNi metal blebs, thus indicating that the grains were partially molten during the shock event. Shock-induced peak pressures and temperatures in the veins were estimated to have exceeded 45 GPa and 1000°C, respectively [4].

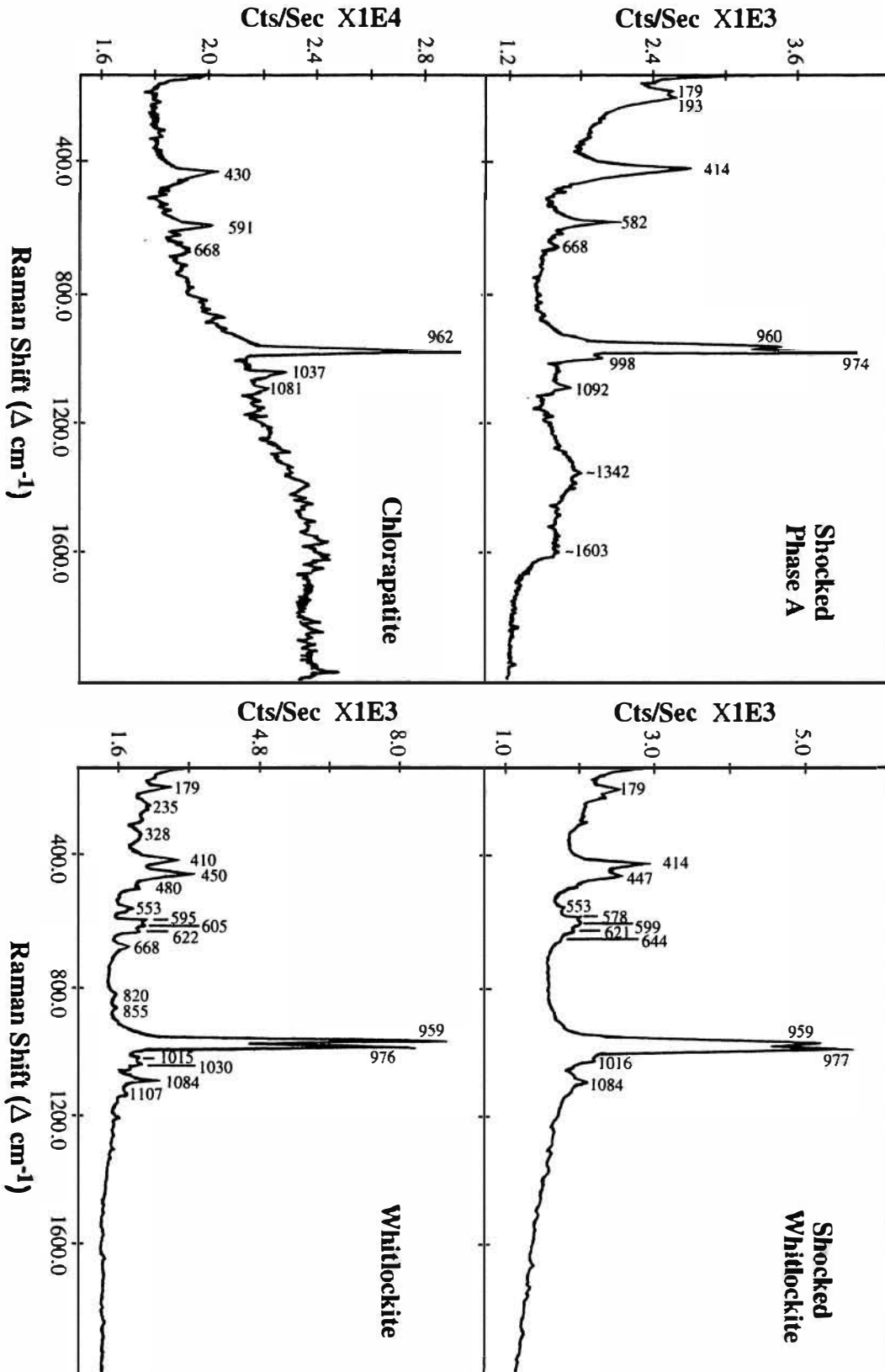
**Optical properties and compositions:** Phase A and shocked whitlockite are isotropic to very weakly birefringent (dark first-order grey). The two phases have less intragranular fractures and other deformation features than the unshocked minerals in the chondritic host. The chemical compositions of the shocked and unshocked phases were quantitatively analysed with the electron microprobe. Phase A has a similar composition as the unshocked chlorapatite, but its Cl content (3.72 wt.%) is lower than that of unshocked chlorapatite (4.84 wt.%). Both phases have different compositions from Bob's Lake monoclinic chlorapatite [5]. The chemical formula of shocked whitlockite  $[(\text{Ca}_{2.49}\text{Mg}_{0.26}\text{Na}_{0.25}\text{Fe}_{0.03})_{3.03}(\text{PO}_4)_{1.97}]$  is identical to that of unshocked whitlockite.

**Raman spectroscopy:** Spectroscopic investigations with a Raman microprobe were conducted on unshocked chlorapatite and whitlockite as well as on phase A and shocked whitlockite (Fig.1). The Raman spectrum of the unshocked chlorapatite is in excellent agreement with the literature [6]. However, the spectrum of phase A is distinctively different from both the unshocked hexagonal apatite and Bob's Lake monoclinic apatite: 1) the 962  $\text{cm}^{-1}$  peak is split into three peaks in phase A, which implies a distortion of the  $\text{PO}_4^{3-}$  tetrahedra, and is consistent with a decrease in symmetry of the original hexagonal crystal structure; 2) the 1081  $\text{cm}^{-1}$  peak of apatite is shifted to 1092  $\text{cm}^{-1}$ ; 3) the 430  $\text{cm}^{-1}$  and 591  $\text{cm}^{-1}$  peaks are shifted to lower wavenumbers; and 4) the intensity of the background (probably caused by fluorescence of trace elements) is decreased by an order of magnitude. Differences in the Raman spectra of shocked and unshocked whitlockite are: 1) the peak widths are increased in the shocked phase; 2) the intensities are decreased; and 3) the peaks are less well resolved. All those observations are characteristic for shocked minerals, and indicate some structural disordering even though the basic crystalline structure remains unchanged.

**Conclusions:** 1) Optical studies and Raman spectroscopy indicate that phase A is a new high-pressure polymorph of chlorapatite. 2) The hexagonal structure of chlorapatite was destroyed at the shock-induced high pressures (>45 GPa) and temperatures (>1000°C) that the meteorite experienced. It was transformed to a probably more dense crystalline polymorph (phase A). 3) The crystal symmetry of whitlockite remained unaffected by this shock event; However, the experienced shock is still manifested in observed small changes in the Raman spectrum (e.g., peak broadening) that are indicative of slight lattice disordering typical for shocked minerals. 4) The cooling rate in the shock veins was very fast ( $7 \times 10^4$  °C). This must have led to the quenching and survival of both phosphates in the shock-veins of Sixiangkou. X-ray studies of phase A and the shocked whitlockite are planned.

**References:** [1] Fuchs, L.H. (1969) in Millman P. M. (ed.) *Meteorite Research*, 683-695. [2] Chen, M. *et al.* (1995) *Meteoritics*, In press. [3] Chen, M. and El Goresy, A. (1994) *Meteoritics*, **29**, 456. [4] Binns, R.A. (1970) *Phys. Earth Planet. Interiors*, **3**, 156-160. [5] Hounslow, A.W. and Chao, G.Y. (1970) *Canad. Min.*, **10**, 252-259. [6] O'Shea, D.C. *et al.* (1974) *Archs oral Biol.*, **19**, 995.

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**Fig. 1. Microsampling Raman spectra (obtained with an ISA S-3000 laser Raman microprobe) of phosphates in the Sixiangkou chondrite.**