

## CHARACTERIZATION OF ANNAMA H5 ORDINARY CHONDRITE USING X-RAY DIFFRACTION, MAGNETIZATION MEASUREMENTS AND MÖSSBAUER SPECTROSCOPY.

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**Introduction:** Annama meteorite fell on April 19, 2014 in the Kola Peninsula (Russian Federation). Two small fragments of this meteorite were found by the Meteoritical Expedition from the Ural Federal University. Annama was classified as H5 ordinary chondrite. One fragment was extensively studied by the international research consortium [1]. In the present work we report studies of Annama H5 meteorite by means of X-ray diffraction (XRD), magnetization measurements and Mössbauer spectroscopy with a high velocity resolution.

**Materials and Methods:** Polished section of an Annama H5 fragment was prepared for characterization by (i) optical microscopy using Axiovert 40 MAT optical microscope (Carl Zeiss) and (ii) scanning electron microscopy (SEM) with energy dispersion spectroscopy (EDS) by means of an Auriga CrossBeam SEM (Carl Zeiss) with an X-max 80 EDS device (Oxford Instruments). Then the surface of the matter was mechanically removed by sandpaper to obtain powder for XRD, magnetization measurements and Mossbauer spectroscopy studies. XRD pattern was measured using XRD-700 diffractometer (Shimadzu) operated at 40 kV and 30 mA with CuK<sub>α</sub> radiation. Magnetization measurements were performed using SQUID magnetometer MPMS-5S (Quantum Design). The room temperature Mössbauer spectrum was measured using SM-2201 spectrometer with a high velocity resolution.

**Results and Discussion:** Characterization of Annama H5 polished section by optical microscopy and SEM with EDS demonstrated the presence of: (i) silicate phases, (ii) troilite FeS, (iii) Fe-Ni-Co alloy consisting of: (a) α-Fe(Ni, Co) phase with Ni variation of ~4–7 at.%, (b) α<sub>2</sub>-Fe(Ni, Co) phase with Ni content ~9 at.% and (c) γ-Fe (Ni, Co) phase with Ni variation of ~30–50 at.%, (iv) chromite (FeCr<sub>2</sub>O<sub>4</sub>) with the presence of ~3 at.% Al, indicating possible presence of hercynite (FeAl<sub>2</sub>O<sub>4</sub>). Full profile Rietveld analysis of the XRD pattern indicated the presence of: (a) ~38.6 wt.% olivine (Fe, Mg)<sub>2</sub>SiO<sub>4</sub>, (b) ~36.6 wt.% orthopyroxene (Fe, Mg)SiO<sub>3</sub>, (c) ~9.0 wt.% α-Fe(Ni, Co) phase, (d) ~5.6 wt.% troilite, (e) ~4.7 wt.% anorthite CaAl<sub>2</sub>Si<sub>2</sub>O<sub>8</sub>, (f) ~2.7 wt.% chromite, (g) ~1.4 wt.% clinopyroxene (Fe, Mg, Ca)SiO<sub>3</sub>, (h) ~1.3 wt.% γ-Fe(Ni, Co) phase and (i) ~0.2 wt.% hercynite. The unit cell parameters for the olivine crystals are: a=10.2476(9) Å, b=6.0026(7) Å, c=4.7671(5) Å and those for the orthopyroxene crystals are a=18.2746(8) Å, b=8.8493(7) Å, c=5.2044(7) Å. Magnetization measurements indicated the chromite Curie temperature at ~60 K, as well as the saturation magnetic moment M<sub>S</sub>=38.9 emu/g at 5 K and a small coercive field H<sub>c</sub>=16 Oe which characterize the Fe-Ni-Co alloy phases. The Annama H5 Mössbauer spectrum consisted of various components was fitted in the same manner as the latest Mössbauer spectra of H, L and LL ordinary chondrites [2, 3]. The best least square fit of this spectrum showed the presence of 8 magnetic sextets, 5 quadrupole doublets and 2 singlets which were related to the ferromagnetic α<sub>2</sub>-Fe(Ni, Co), α-Fe(Ni, Co), γ-Fe(Ni, Co) and γ-FeNi phases and to the paramagnetic γ-Fe(Ni, Co) phase, to troilite, to the M1 and M2 sites in olivine and orthopyroxene, to chromite and to hercynite on the basis of their hyperfine parameters. The relative areas A of spectral components associated with corresponding iron-bearing phases indicated the phase composition (relative iron content) in Annama H5 ordinary chondrite.

The occupation ratios of Fe<sup>2+</sup> in the M1 and M2 sites in silicates can be determined and compared using XRD and Mössbauer data. The cation partitioning values derived from XRD are: X<sub>Fe</sub><sup>M1</sup>=0.21, X<sub>Mg</sub><sup>M1</sup>=0.79, X<sub>Fe</sub><sup>M2</sup>=0.17 and X<sub>Mg</sub><sup>M2</sup>=0.83 for olivine and X<sub>Fe</sub><sup>M1</sup>=0.06, X<sub>Mg</sub><sup>M1</sup>=0.94, X<sub>Fe</sub><sup>M2</sup>=0.48 and X<sub>Mg</sub><sup>M2</sup>=0.52 for orthopyroxene. The ratios of Fe<sup>2+</sup> occupancies are: X<sub>Fe</sub><sup>M1</sup>/X<sub>Fe</sub><sup>M2</sup>=1.24 for olivine and X<sub>Fe</sub><sup>M1</sup>/X<sub>Fe</sub><sup>M2</sup>=0.13 for orthopyroxene. The ratios of Fe<sup>2+</sup> occupancies deduced from the relative areas of corresponding spectral components in the Mössbauer spectrum are: A<sub>M1</sub>/A<sub>M2</sub>=1.42 for olivine and A<sub>M1</sub>/A<sub>M2</sub>=0.23 for orthopyroxene. These ratios obtained from two independent techniques appeared to be in good agreement. Using these values, the method described in [4] and the values of Fa=18.6 and Fs=16.6 for Annama H5 [1] it is possible to estimate the temperature of cation equilibrium distribution T<sub>eq</sub>. The results obtained using both techniques are: T<sub>eq</sub>=966 K (XRD) and T<sub>eq</sub>=592 K (Mössbauer data) for olivine and T<sub>eq</sub>=720 K (XRD) and T<sub>eq</sub>=1035 K (Mössbauer data) for orthopyroxene.

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