HIGH PRESSURE STUDIES ON PIPLIA KALAN METEORITE: ROLE OF ANORTHITE IN THE DETERMINATION OF RESIDUAL STRESS DUE TO SHOCK IMPACT. Usha Chandra[1] , K.K.Pandey[2] , G.-Parthasarathy[3] and Surinder M.Sharma[2], [1]Department of Physics, University of Rajasthan, Jaipur 302004 (India) chandrausha@hotmail.com , [2] High pressure & Synchrotron Radiation Physics Division, BARC,Trombay, Mumbai 400085(India), [3]CSIR-National Geophysical Research Institute, Uppal Road, Hyderabad 500007 (India).

Introduction: Meteorites provide the information about the bulk composition of its parent asteroids or planets.The parent body suffer violent collisions re-equilibrating thermodynamically its minerals phases at various pressures. The process of crystallization and amorphization provides some information about the impact processes as well as environmental conditions on the parent body. High-pressure laboratory experimentation,therefore, provides a tool to measure the pressure of transition. Here we report high pressure XRD and Mössbauer spectroscopic measurements on Piplia Kalan meteorite , a eucrite which fell in Pali district of Rajasthan during the year 1996 [1]. The elemental anlysis using XRF showed (in weight %) Si= 22.82; Fe=15.25; Mg=3.92;Al=6.55;Ca=7.35 and Ti= 0.50 classifying it as a eucrite. EPMA showed pyroxene content as $En_{32-36}Fs_{60-65}Wo_{2-5}$ and plagioclase feldspar to be anorthite rich (90mol%).

Method: In-situ high-pressure x-ray diffraction experiment was carried out up to 16GPa in an angle-dispersive mode using monochromatic x-rays (λ=0.6255Å) at EDXRD beam line located at a bending magnet port BL-11 at INDUS 2 Synchrotron source at RRCAT, Indore (India) and Mao-Bell DAC with diamond culet ~ 400 µm.Sample chamber was pre-indented tungsten carbide gasket with 200 µm hole filled with silicon oil as pressure transmitter, 2D diffraction images were recorded using MAR345 image plate detector with beam dimension 200x200µm.Sample-detector distance, detector tilt-rotation and x-ray wavelength were corrected using CeO_2 powder as calibrant [2]. For Mössbauer spectroscopic measurements (up to 8GPa),Merrill Bassett DAC was used with sample assembly consisting of tantalum gasket with 200 µm hole containing ruby crystals for pressure measurements and 4:1 ethanol:methanol mixture as pressure transmitting medium.The data were collected using 10mCi point source, Si-PIN noise less solid state detector and CMCA-550 data acquisition module[3].

Results and Discussions: Fig. 1 compares XRD pattern of the DAC encapsualted sample with that of the raw powder.The dominant minerals are anorthite,monoclinic ferrosilite and clinoenstatite.Inspite of variation in the intensity due to the presence of very few grains inside DAC, the peaks due to dominant minerals could be seen prominently[4].

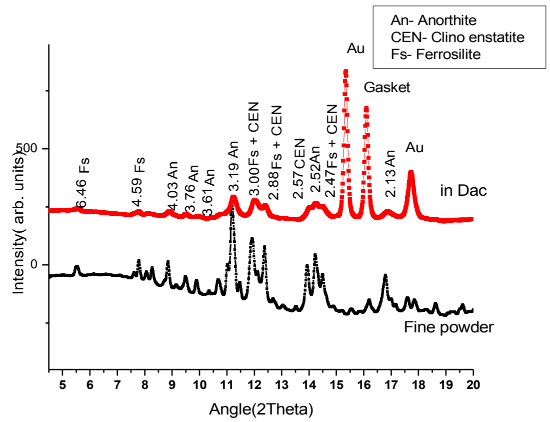

Fig. 1. Comparison of XRD patterns of raw powdered Piplia Kalan meteorite with that encapsulated inside DAC.

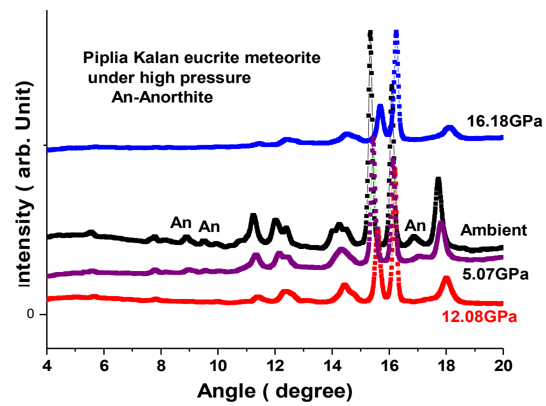

Fig 2. XRD patterns of Piplia Kalan meteorite at various pressures inside DAC.

Fig.2 displays pressure dependent XRD patterns of the Piplia Kalan meteorite at various pressures. The variations in the pattern between ambient and 5GPa could be explained by $P2_1/c$ to C2/c displacive phase transition in ferrosilite and pyroxene [5,6].Terrestrial anorthite because of its sensitivity towards the pressure has shown an onset of amorphization between 10 to 14 GPa followed by a total irreversible amorphization at about 20GPa [4,7].The prominent peaks corresponding to the mineral marked as ‘An’ in the figure indicate loss of intensity around 5 GPa , eventually becoming amorphous at 12GPa. At 16 GPa , amorphization of other components are also visible through broadening of peaks.

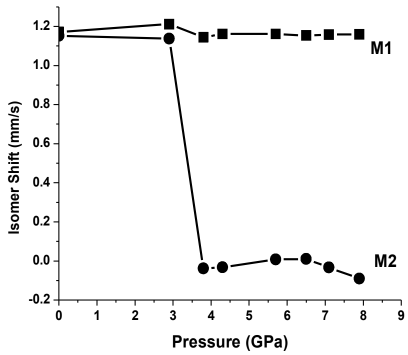

Fig.3 Pressure -dependentvariation in isomer shift in Piplia Kalan meteorite.

Pigeonite rich pyroxene have two inequivalent distinctive octahedral sites M1 and M2 , Fe preferring more distorted M2 site. Mössbauer spectroscopy, a sensitive tool to probe Fe nuclei through its parameters- isomer shift and quadrupole splitting is sensitive towards applied pressure.Isomer shift at ambient pressure suggested divalent Fe preferring occupation in M2 site but it showed large variation with pressure while M1 site remained almost undisturbed (Fig 3.).

Table 2: Pressure dependent variation in Isomer shift for Piplia Kalan meteorite at various pressure ranges.

Pressure range ((GPa)	Site	Pressure coefficient of Isomer shift δ(IS)/δP (mm/s/GPa)
Ambient – 2.9 GPa	M1 M2	+ 1.7×10^{-3} - 4.82×10^{-3}
2.9 – 3.8 GPa	M1 M2	- 7.4×10^{-2} - 1.30
3.8-6.5 GPa	M1 M2	+ 3.3×10^{-3} + 1.81×10^{-2}
6.5 -7.9 GPa	M1 M2	+ 4.28×10^{-3} - 7.21×10^{-2}

The pressure coefficient of isomer shift δ(IS)/δP between 2.9 to 3.8GPa showed largest slope fro both M1 and M2 sites(Fig 3,Table 2). This negative pressure coefficient accompanied by inversion in the population could be corresponding to $P2_1/c$ to C2/c phase transition seen by XRD[8].The positive pressure coefficient between 3.8 to 6.5GPa conjugated with sharpness of peaks in XRD patterns could suggest reaarangement of atoms in the various lattice planes.-Though Fe-free anorthite could not be detected by Mössbauer technique , however any changes in the environment would appear as changes in the Mössbauer parameters. The onset of amorphization by anorthite , thus could be visualized as negatice pressure coefficient above 6.5 GPa (Table 2).

A case study on Lohawat Howardite meteorite - another member of HED (Howardite-Eucrite-Diogenite) family originated from the same asteroid 4-Vesta showed interesting results .The chemical composition of the sample was orthopyroxene ($En_{34}Fs_{65}Wo_1$) with 94% anorthite rich plagioclase. High pressure study on the sample showed interesting pressure-induced irreversible amorphization in anorthite at 2.8GPa followed by reversible crystallization in pyroxenes at 5.6 GPa [9].

Both Lohawat and Piplia Kalan meteorites,having the same origin are classified as Howardite and eucrite respectively. Both contained plagioclase feldspar with 90% anorthite.The response of the mineral with applied pressure in these samples, different from the terrestrial behavior, facilitated in estimating the peak shock pressure experienced by the meteorites during ejection from the parent body. Irrevesible amorphization took place at ~ 3GPa and 12 GPa in Lohawat and Piplia Kalan meteorites respectively instead of 20 GPa reported for terrestrial anorthite.

Interestingly, in Lohawat meteorite orthopyroxene did not respond to the pressure up to 9GPa while monoclinic pyroxene and ferrosilite in Piplia Kan meteorite revealed a displacive phase transitions at very low pressure of 3.5GPa.

Our pressure dependent study on the meteorites demonstrate that such studies not only could provide estimation of peak shock pressure but also would suggest environmental information about the genesis. Sensitivity of aniorthite mineral plays an important role in estimating the peak shock pressure due to impact processes.

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References: [1]Vaya et al. (1996) *Current Sc.*71,253.[2] Pandey et al.(2013) *Pramana-J.Phys*. 80(4),607. [3] Chandra et al. 2005 *Hyp.Int*. 163,129. [4] Redfern S.A.T. (1996) *Min.Mag.* 60,493.[5] Yu Y.G. et al. (2010) J. Geophys.Res.115,B02201.[6] Alvaro M.et al. (2010) Am. Miner.95,306.[7] Daniel I.et al.(1995) Am. Miner 80,645.[8] McCammon C.A. and Tennant C.(1996) Min. Spectro:A tribute to Roger G.Burns, Geochem Soc. Sp. Publ.5 ed. Dyar et al. 281[9]Chandra U. et al. (2013) *Chem der Erde* 73(2), 197.