SULFIDE-RICH CHONDRULE RIMS IN BISHUNPUR (L3) CHONDRITE: TYPES, TEXTURES, MINERALOGY AND GENETIC IMPLICATIONS. El Goresy, A.[+], P. Ramdohr[+], and E.R. Rambaldi[x], [+]Max-Planck-Institut f. Kernphysik, Heidelberg, F.R.G.; [x]Institute of Geophysics and Planet.Physics, UC, Los Angeles, CA 90024, USA.

In unequilibrated ordinary chondrites both sulfide-rich and sulfide-poor rims are characterized by the non-clastic nature of the grains (1). The sulfide-rich rims consist of either fine troilite grains mixed with various kinds of silicates, or troilite and metallic FeNi grains+silicates (2,4). Textures and compositions of chondrule rims in unequilibrated ordinary chondrites may have preserved important genetic informations as to the last events the chondrules went through, just before they were assembled along with their rims with the meteorite matrix. We have conducted a detailed transmitted and reflected light, SEM and electron microprobe study of the rimming features in the Bishunpur (L3) chondrite. Special interest was devoted to the following aspects: a) are sulfide rims restricted to chondrules? b) are all sulfide rims identical in texture, mineralogy and mineral chemistry? c) is troilite the only sulfide present?, and d) how far does troilite in which assemblage deviate from stoichiometry? (2), and what is the trace element household, e.g. Ca of troilite in the rims? (4).

Textures and Mineralogy of Rims. Rimming features in Bishunpur are by no means confined to chondrules but were also found around FeNi, complex FeNi-troilite, and silicate lithic clasts. Lithic clasts in other unequilibrated ordinary chondrites also display this phenomenon (3). In the present investigations, four different types of sulfide-rich rims were encountered on chondrules, however, not all types occur on clasts: 1. compact troilite rims with olivine microphenocrysts. This type appears to be restricted to chondrules. The rim thicknesses vary usually between 20 and 50μm, however, may reach 100 μm in some depressions on the chondrule surfaces. At low magnification, the texture resembles an aggregate of angular grains of troilite and silicates. SEM studies indicate, however, a massive non-porous nature of an assemblage of large troilite crystals with numerous microphenocrysts (up to 10μm long) of olivine. We interpreted this texture as evidence for deposition of a sulfide-silicate liquid around the chondrules which crystallized to idiomorphic olivine+troilite. The texture thus negates mechanical accretion of an aggregate of troilite+olivine, 2. aggregate of troilite, metallic FeNi and silicate grains. This is a quite abundant rim type encountered on chondrules, FeNi metal- and silicate lithic clasts. The thickness varies widely and may reach up to 400μm. Grain size of troilite and FeNi changes radially from the chondrule or clast surface to the meteorite groundmass thus indicating the presence of several alternating layers of non-clastic mineral aggregates. As many as 6 successive alternating layers may be encountered. On some chondrules and metal clasts the first layer consists of a discontinuous thin shell of troilite. However, the troilite and FeNi grain size in the succeeding layers may vary wildly indicating fast accretion of non-sorted grains. 3. This type is unique both in texture and composition. It is encountered on few porphyritic chondrules and FeNi clasts. It is characterized by rhythmic layering of troilite, fayalite and a new mineral: a Fe, Cr, Ca oxysulfide-phosphide-silicide (here called mineral X). The sequence of the layers is identical both on chondrules and clasts and usually starts with a porous troilite-FeNi aggregate followed by mineral X, then by rhythmic almost continuous, delicate, alternating layers of troilite (or pyrrhotite) and fayalite (Figs. 1a,b, 2). The number of layers is quite variable even on the same chondrule or clast. The last layer is sometimes overlain by a broad shell (∿30μm) of very fine aggregate of silicates (Fig.3). On some chondrules the layers are interrupted laterally and there is evidence of mechanical removal of the outermost layers before inclusion in the meteorite groundmass. Within the small thickness of this type of rim, the mineralogical and chemical evidence is indicative of a dramatic change during the course of layering, i.e. more oxidizing and more sulfur-rich. This layering texture resembles in many aspects the features observed around Ca-Al-rich inclusions in Allende. 4. This type usually occurs as an almost complete shell of troilite almost armoring the chondrules. It consists of an aggregate of relatively coarse troilite grains (20μm). Metallic FeNi is also present, specifically enriched in depressions in the chondrule surface. Their troilite-metal relationship is unique: FeNi aggregates always occupy the core of the depression and are surrounded by troilite and silicates with a tight rim of troilite thus giving it a "bird-eye structure". The fine-grained silicate material between the FeNi-core and the troilite rim is always highly enriched in P, Cr, and Ca.

Mineral Chemistry. In order to construct a logical framework for the chemical characteristics of the individual minerals in the rims, detailed analyses were also performed on metal and troilite clasts. It became evident then that those clasts were earlier classified as "groundmass" metals and troilites. In agreement with (4), kamacites in type 2 and type 3 rims show indeed a higher Co-content (0.65-0.79 wt.%) than many kamacites in metal clasts. In type 4 rims the Co-content of kamacite is indistinguishable from kamacites in the majority of the clasts (0.34-0.53 wt.%). However, it is characterized by the presence of Cr (0.30-1.05 wt.%). Contrary to (5), many of the taenites in the clasts are not of the clear type. Allen et al. (2) report that analyses of troilite in rims in Chainpur (LL3) show departure from stoichiometric FeS composition. To investigate if this phenomenon is present in troilite rims of Bishunpur, we carried out accurate analyses using several synthetic standards with well defined compositions as continuous monitors. Troilites in Chainpur rims show a wide range in composition (2) between $Fe_{0.989}S$ and $Fe_{1.117}S$. Applying our new analytical technique, the troilite compositions in the various rim types are 1. $Fe_{1.001}S$-$Fe_{1.008}S$; 2. $Fe_{0.944}S$-$Fe_{1.04}S$; 3. $Fe_{1.012}S$; 4. $Fe_{0.956}S$. Apparent deviation from stoichiometry to higher Fe values exceedingly increases if this method is not applied. Our results, though unsatisfactory, indicate that analytical error is another plausible explanation for the higher Fe contents reported by (2) and by us. Deficiency of Fe towards pyrrhotite compositions are well pronounced in many analyses in type 2 and 4 rims. Minor element chemistry of troilites of the 4 rim types indicates distinct compositions and hence suggests different formational processes: 1. pure stoichiometric FeS; 2. P is the only minor element detected (neighboring phosphates?); 3. 0.15-0.36% Ca (in agreement with (4)), 0.3-0.65% Cr, 0.18% P; 4. up to 1% Cr, 0.5% P and 0.34% Ni. Table 1 shows the composition of new mineral X. The low totals are presumably due to the presence of oxygen since the optical properties are suggestive of an oxysulfide. Carbon and/or N cannot be ruled out and accurate analyses are in progress.

TABLE 1.

	Cr	Fe	Co	Ni	Ca	Mg	S	P	Si	Totals
1	0.66	49.2	-	0.04	1.58	0.68	25.4	0.87	5.80	84.23
2	0.12	50.2	-	0.02	3.86	0.43	28.2	1.96	2.67	87.46

Mineral X is isotropic and shows a reflectance lower than that of troilite. Reflectance colour: dark brown and is quite close to that of djerfisherite.

Genetic Implications. Sulfide-rich rims on chondrules and clasts in Bishunpur are formed by a variety of processes. Everyone has its own fingerprint in texture and chemistry of the rimming minerals. Type 1 is formed by coating chondrules with a sulfide-rich liquid; type 2 by mechanical accretion. Texture and chemistry of type 3 are indicative of condensation of delicate layers from a gas continuously changing in composition, i.e. oxidizing. Condensation in the solar nebula is the most plausible explanation. This puts a severe constraint as to the origin of chondrules. Type 4 may be formed by a related process, however, texture and chemistry are not indicative of an impact process.

References. (1) Ashworth J.R. (1977) EPSL 35, 25-34. (2) Allen J.S., Nozette S. and Wilkening L.L. (1980) Geochim.Cosmochim. Acta 44, 1161-1176. (3) King T. and King E.A. (1980) Lunar Planet.Sci. XI, 557-559. (4) Rambaldi E.R. and Wasson J.T. (1980) Meteoritics 15, Dec. issue, in press. (5) Affiatalab F. and Wasson J.T. (1980) Geochim.Cosmochim. Acta 44, 431-446.

Fig. 1a

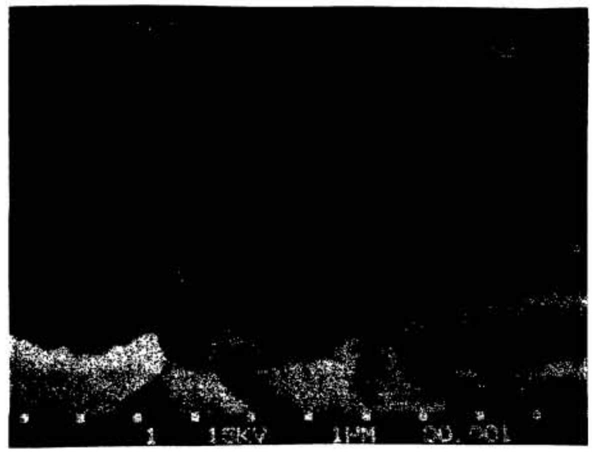

Fig. 1b

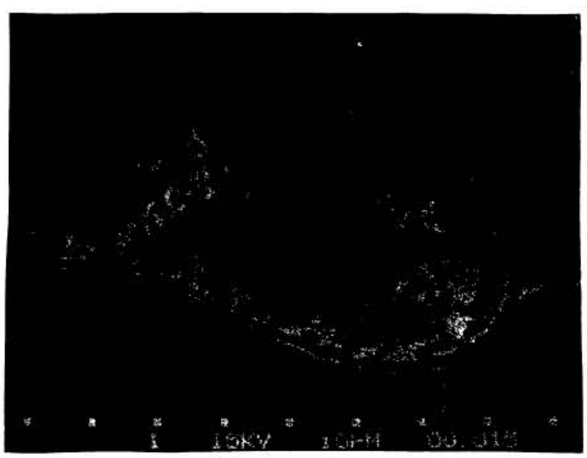

Fig. 2

Fig. 3