METAL OF HIGH Co CONTENT IN LL CHONDRITES

D.W. Sears and H.J. Axon
Department of Metallurgy
University of Manchester
U.K.

Measurements on the metal of the LL chondrites Appley Bridge, Jelica, Olivenza, and Khanpur have shown that the Co:Ni ratio of the metal is near 1.24 and that Prior's law appears to be followed to some extent within the LL group.

We have made a metallographic and microprobe study of the metal in four chondrites of the LL type. Appley Bridge and Jelica are both of petrologic grade six and contain identical quantities of total Fe, 20.1 percent (Wiik, 1969) and 20.2 percent (Nichiporuk *et al.*, 1967) respectively. They contain similar proportions of metallic phase which is distributed as 10-50 μm particles of compositionally homogeneous taenite that is rich in both Ni and Co. We have not encountered kamacite in Appley Bridge, although in Jelica one particle of kamacite was encountered in contact with taenite and the kamacite had Ni and Co contents of 4.79 percent and 9.55 percent, respectively. The absence of compositional zoning and two-phase structures in the metal means that for these meteorites the microprobe analysis of individual metal grains should be related in some simple manner to the bulk composition of the metallic phase as determined by conventional chemical analysis. The microprobe analyses of individual grains from Appley Bridge and Jelica are plotted as vertical crosses and circles respectively in Fig. 1. It may be seen that these particles of chondritic metal lie above the linear extrapolation of the "meteoritic" range of NiCo contents which is based mainly on iron meteorites (Moore *et al.*, 1969; Goldstein and Yakowitz, 1971) and below the "cosmic" Co:Ni ratio of 1:20 (Cameron, 1973). A line fitted to the data by the method of least squares indicates a Co:Ni ratio of 1/23.6 with 95 percent confidence limits of 1/21.6 and 1/26.0. The probability of the Co:Ni ratio equalling the "cosmic" value of 1/20 is therefore very much less than 0.05. The line drawn through the data corresponds to a Co:Ni ratio of 1.24. In addition to the grey matrix material similar to the other LL chondrites, Jelica contains dark material in which the silicates are glassy. However, we have examined and analysed five metal grains located in this material and found them indistinguishable from those plotted for the light variety of Jelica in Fig. 1.

Figure 1 also shows the microprobe analyses for single-phase taenite particles in the LL5 chondrites Olivenza and Khanpur. The relationship between microprobe analyses and bulk analyses is less straightforward for the metal in these samples, since in both instances the larger particles of metal tend to show a two-phase structure with minor quantities of kamacite in

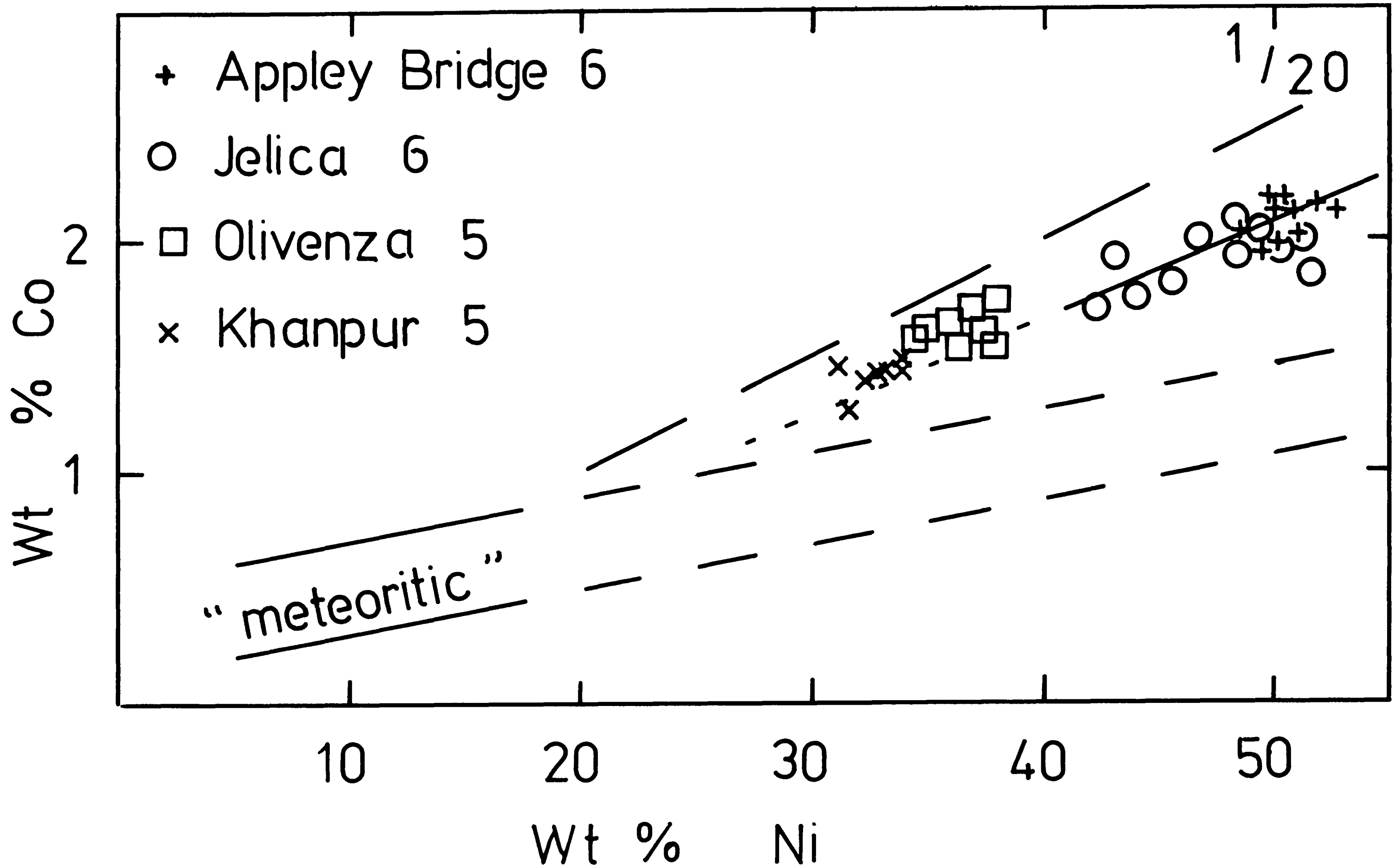

Fig. 1. A plot of the Ni and Co contents of individual grains of metal from four LL chondrites compared with the cosmic abundance ratio of 1/20 and an extrapolation of the range observed in iron meteorites. The line through the points has a slope of 1/24. The petrologic class of each meteorite is indicated.

taenite. The taenite has a characteristic uniformly etched appearance and a clear rim. However, kamacite is not abundant and the data points of Fig. 1 refer to single-phase taenite only. The total Fe content of Olivenza at 25.9 percent (Greenland and Lovering, 1965) is higher than for the two LL6 meteorites and, unfortunately, no total analysis is available for Khanpur. Nevertheless, within the limits of uncertainty the data points for both of the LL5 meteorites fall on an extension of the CoNi line that was established by the more reliable observations on the LL6 chondrites.

In addition, we have examined the metal in three other LL chondrites, namely Dhurmsala LL6, total Fe 19.4 percent (Nichiporuk *et al.*, 1967); Mangwendi LL6, total Fe 19.8 percent (Greenland and Lovering, 1965); and Soko-Banja LL4, total Fe 20.1 percent (Prior, 1916). In these three meteorites the metal phase is more profuse and exists as both kamacite and compositionally zoned plessite; consequently, it is less easy to relate the microprobe measurements of individual grains to the bulk composition of the metal phase. However, the kamacite compositions for these three meteorites are all about five percent Ni and two percent Co. Since some of the co-existing taenite is compositionally zoned, it does not yield reliable values of average composition, but it is generally depleted in Co (say ~ 0.5%) and enriched in nickel (say ~ 30-40%) with respect to the kamacite. The bulk composition of the metal in Dhurmsala, Mangwendi and Soko-Banja must lie between these single phase kamacite and taenite compositions and is clearly much lower in Co and Ni than the previously discussed meteorites.

Prior's law appears to be followed to some extent within this suite of LL chondrites, unlike the situation with H and L chondrites, which do not obey the law within the groups (*e.g.* Keil and Fredriksson, 1963; Craig, 1964). The LL chondrites Dhurmsala, Mangwendi and Soko-Banja that have lower contents of Co and Ni, and hence higher contents of Fe, in their metallic phase contain olivine with fayalite contents of 27.2, 29.5 and 28.8 mole percent, respectively; while Khanpur and Olivenza have 29.0 and 29.8 mole percent and Jelica and Appley Bridge have 32.3 and 31.1 mole percent, respectively (Mason, 1963; Fredriksson *et al.*, 1968). The correlation between Ni content of metal and fayalite content of the olivine is in accord with Prior's law, although the values for Jelica and Appley Bridge should be reversed and Mangwendi's value is high.

In Fig. 1 the point analyses for individual metal grains in Appley Bridge, Jelica, Olivenza and Khanpur plot along a line of constant Co:Ni ratio equal to 1:24. It appears that the same driving force that causes the meteorites to distribute themselves along the 1/24 line, and which gives rise to Prior's law, is also operative *within* the individual meteorites. Thus, not only is there a Prior's law relationship between the *bulk* metal composition of the four separate meteorites, but there is also a similar relationship between the individual metal grains within each meteorite. Thus for these well consolidated LL chondrites it seems that Prior's law was operative at a highly localised level on the metal within each of these meteorites.

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