SILICATES IN IAB AND IIICD IRONS, WINONAITES, LODRANITES AND BRACHINA: A PRIMITIVE AND MODIFIED-PRIMITIVE GROUP

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INTRODUCTION: Silicate inclusions in IAB and IIICD irons have been characterized as "primitive", in a broad sense (1,2), and winonaites are a genetically related group (3). San Cristobal, however, is a IAB iron which has undergone some melting, because its silicate inclusions are rich in phosphate and roedderite (reported here for the first time). Kendall Co. is ungrouped, with extremely reduced silicates, but near IAB (4). Other meteorites we now consider may be related to these chemically primitive or modified-primitive groups are lodranites and Brachina, on the basis of new mineralogic, trace element and oxygen isotopic data. Lodran was a unique stony-iron (5,6), but a new lodranite containing feldspar has been found in Antarctica (7) making it more like IAB silicates, etc. Brachina is no longer a chassignite, but is considered almost primitive (8). Oxygen isotopes of both groups are close to the mass frationation line with IAB silicates (9).

The purpose of this study is to bring together all relevant data on these meteorites and examine the relationships of this newly reorganized grouping. Some members are modified by reduction and/or minor partial melting processes, and these are emphasized in order to understand their later processing.

New petrologic data were collected on 23 meteorites; 13 IAB irons, 2 IIICD irons, 5 winonaites, Kendall Co., Lodran and Brachina. Bulk compositions were calculated from modal compositions, and helped resolve problems posed by rusting of metal and troilite.

Modes: Modal data are presented in Fig. 1. IAB silicates and winonaites are similar and have consistently lower ol/opx ratios than ordinary chondrites. San Cristobal differs markedly from the others; it has 18.9% brianite, 2.7% merrillite, 5.4% roedderite and no cpx, in addition to ol, opx and plag. For IIICD irons, Carlton has silicates similar to those in IAB, but contains a farringtonite-brianite phosphate. Dayton has a highly fractionated assemblage, with 77% phosphate, mostly brianite and panethite. Kendall Co. has 57% cpx, and 25% tridymite (4), and Brachina is highly enriched in olivine (8). Lodran silicates are essentially half ol and half opx.

Ol/opx generally increases systematically from IAB silicates and winonaites, to IIICD silicates to lodranites to Brachina, although sampling is sparse for the latter groups.

Mineralogy: Mineralogical data for these meteorites are shown in Fig. 2, and compared with H, L, and LL chondrites. The main results are: (1) IAB and IIICD silicates, winonaites, Lodran and Brachina have a wide range of Fe/Mg ratio. Opx in the most common IAB silicates is En_{90-95}, with Pine River at En_{99}. Opx in winonaites has a wider range, En_{86-99}. Opx in IIICD silicates is more Fe-rich, En_{88-90}, lodranites are En_{84-88}, and Brachina is En_{70}. (2) Plag in IAB silicates and winonaites is usually An_{10-20}, Or_{2-4}; some is as low as An_3 (Pitts); grain to grain variability is fairly common. IIICD plag is more albitic, An_{1-6}. Yamato lodranite has An_{16-18} (7) and Brachina has An_{22}. Kendall Co. has a unique range from An_{11-49} (3). Ol and opx do not appear to be equilibrium pairs, as shown in Fig. 2, except for Brachina. Olivine compositions are too Mg-rich for coexisting opx, when contrasted with equilibrium ol-opx pairs (10); this may be due to reduction of Fe in ol, and is discussed below.

Discussion: (1) Most IAB silicates and winonaites are modally, mineralogically and chemically only slightly fractionated. They have mineralogy similar to that in chondritic meteorites but contain no chondrules. Textures are recrystallized, generally equigranular, and do not reveal any precursor textures or mineralogy. (2) The sequence IAB silicates and winonaites to IIICD silicates to lodranites to Brachina has increasing ol/opx, with increasing Fe/Mg ratio in the silicates. This suggests a genetic relationship between these meteorite groups involving reduction of Fe_2SiO_4 and subsequent reaction of $Mg_2SiO_4+SiO_2=2MgSiO_3$. **(3)** Mg/(Mg+Fe) ratio of the silicates is the result of redox reactions between more Fe-rich silicate precursor minerals and graphite to produce metal in nearly all IAB silicates and winonaites. Lodran contains no detectable carbon, but it must have been present to reduce the outer margins of the ol grains (5,6). Ol appears to have been most affected by reduction in all assemblages, but opx may also have been reduced. The most dramatic reduction effects are found in Kendall Co., Tierra Blanca, Campo del Cielo and Lodran. **(4)** Oxygen isotopic data are consistent with all of these groups or individual meteorites being related along a mass fractionation line below the Earth-Moon line (9). **(5)** The cooling rate of Winona is at least 50 times faster than that in IAB silicates (11). Thus winonaites, with higher silicate/metal ratio, may have been nearer the surface of a parent body, or in a smaller parent body. **(6)** In addition to reduction, heating of the silicates appears to have melted and fractionated troilite, and caused minor partial melting in some assemblages (12). REE patterns in many of the IAB silicates and winonaites indicate some partial melting (2,3,13). Igneous fractionation on a larger scale is indicated for San Cristobal, Dayton and Kendall Co. **(7)** Kendall Co. was produced by extreme but incomplete reduction of a precursor silicate assemblage with an Mg/Fe ratio of 0.7 or lower (4). **(8)** The thermal history of the parent body(ies) of this grouping of meteorites was intermediate between that of ordinary chondrites and fully differentiated achondrites.

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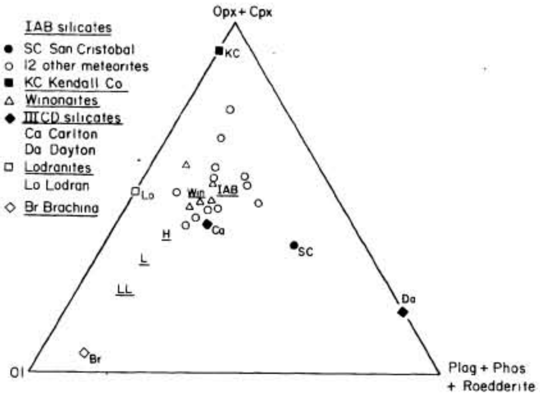

Figure 1

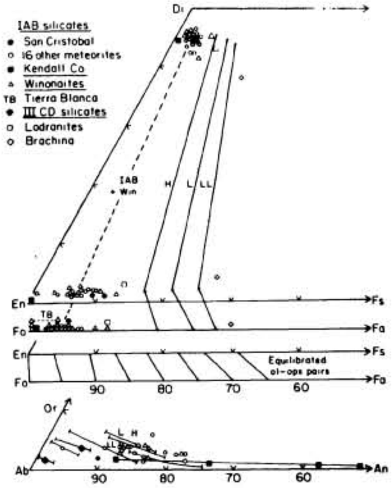

Figure 2