GUJBA: A NEW BENCUBBIN-LIKE METEORITE FALL FROM NIGERIA.

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The Gujba, Nigeria meteorite is the first observed fall (3 April 1984) of a Bencubbin-like meteorite [1]. Gujba texturally resembles Bencubbin and QUE94411 except that, in Gujba, the coarse metal and silicate nodules are round and generally unfragmented. The compositions of the metal and silicates in Gujba are similar to those of other Bencubbin-like meteorites. Gujba consists of three major components: (1) 41 vol.% metal nodules, (2) 20 vol.% large light-colored silicate nodules, and (3) 39 vol.% dark-colored, silicate-rich matrix.

The O-isotopic composition of Gujba silicates is very similar to those of Bencubbin, Weatherford and QUE94411. The respective $\delta^{18}O$, $\delta^{17}O$ and $\Delta^{17}O$ values (in ‰ relative to SMOW) are: Gujba light-colored silicates (+0.53, -2.19, -2.47); Gujba dark-colored silicates (+0.98, -1.78, -2.29); Bencubbin (+0.90, -1.80, -2.27) [2]; Weatherford (+1.69, -1.65, -2.53) [2]; QUE94411 (+1.50, -1.47, -2.25) [3].

Bencubbin-like meteorites are characterized by enrichments in ^{15}N [4], with $\delta^{15}N$ reaching up to +800‰. Dark-colored Gujba silicates have a total nitrogen content of 144 µg/g, with $\delta^{15}N$ ~+685‰. The heaviest nitrogen was released at temperatures characteristic of carbide or metal decomposition, with $\delta^{15}N$ reaching +790‰. The dark-colored silicates are also carbon-rich, with ~0.5 wt.% C.

Gujba metal nodules are ellipsoidal to spheroidal and range in maximum dimension from 400 µm to 7 mm. Because the metal nodules are so undistorted, it is evident that the original whole-rock depositional texture is better preserved in Gujba than in other Bencubbin-like meteorites. The metal nodules contain variable amounts of troilite (<0.01 to ~1 vol.%); no graphite, carbide or phosphide phases were identified. Neutron-activation analyses of six 42-390-mg metal nodules reveal a correlation between troilite-texture/troilite-abundance and the concentrations (in µg/g) of volatile siderophile elements. The highest concentrations of these elements are in nodules 6, 5 and 4 (0.470-0.505 Au; 4.36-5.18 As; 115-207 Cu; 2.17-3.74 Ga); intermediate concentrations are in nodules 1 and 2 (0.342-0.356 Au; 3.00-3.40 As; 32-56 Cu; 1.10-1.55 Ga); and the lowest concentrations are in nodule 3 (0.135 Au; 1.43 As; 10 Cu; 0.61 Ga). Nodule 6 consists of 200-600-µm-wide patches of kamacite separated and, in some cases, partially surrounded, by arcuate patches of troilite. This appears to be a texture produced by rapid cooling; a similar but much coarser texture is present in the IAB-an iron Mundrabilla. Nodules 2, 4 and 5 have fewer arcuate patches of troilite and generally smaller kamacite domains; they contain numerous troilite-free kamacite patches adjacent to ones containing 10-20 vol.% 5-10-µm-size round troilite blebs. (Metal nodules with similar blebby troilite textures occur in Bencubbin [5]). Nodule 1 contains no arcuate troilite but consists of troilite-free kamacite regions adjacent to ones containing 5-10 vol.% 5-10-µm-size round troilite blebs. Nodule 3 is essentially troilite free; there is a single 15×50 µm troilite grain in the plane of the section.

We propose two distinct models to account for the correlation between texture and volatile-siderophile concentrations in the metal nodules. **Model 1**: All of the metal nodules quenched from high temperatures and initially resembled nodule 6. The correlation between troilite texture (and, to a lesser extent, abundance) and volatile-siderophile concentration among the nodules indicates that the nodules were subsequently heated to very high temperatures (perhaps >2000 K) and that troilite and volatile siderophile elements were partially boiled off. Troilite blebs formed from melting arcuate troilite patches. Nodule 3 (with essentially no troilite) experienced the greatest degree of volatilization. **Model 2**: Nodule 3 formed by condensation at high temperatures and nodule 6 at lower temperatures, thus accounting for the differences in their concentrations of S and volatile siderophiles. Other nodules condensed at intermediate temperatures. Arcuate troilite formed from a late-stage S-rich melt that crystallized around solidified metal.

Light-colored silicate nodules are ellipsoidal to spheroidal quench-textured objects ranging in maximum dimension from ~800 µm to 10 mm. Large silicate nodules have cryptocrystalline textures with 50-400-µm-size extinction domains in random orientations. Each individual domain consists of bundles or fan-like arrays of elongated pyroxene crystals ($Fs_{1-2}Wo_{1-3}$) with interadjacent feldspathic glass. Smaller silicate nodule fragments (50-600 µm) exhibit barred pyroxene (BP) or cryptocrystalline (C) textures. In the BP objects, the individual pyroxene bars average ~6 µm in width; in the C-textured objects, the individual bars average 2-4 µm in width. Rare silicate nodules contain olivine ($Fa_{2.6}$). Metallic Fe-Ni is absent from the silicate nodules.

Dark-colored silicate-rich matrix contains small irregular metal nodules (~100 µm) and smaller (2-50 µm-size) irregular metal grains, blebs and veins. Silicates consist mainly of small nodule fragments. In some cases, small metal particles surround silicate nodules; in other cases, small metal veins in the matrix are connected to large metal nodules.

Some shock effects are evident in Gujba. Olivine and low-Ca pyroxene exhibit undulose extinction, characteristic of shock stage S2. In some places, there is a fine-grained dispersion of metal and silicate that closely resembles the texture of shock veins in ordinary chondrites except that, in Gujba, troilite is essentially absent from the opaque-mineral dispersion. Some large metal nodules contain patches of cellular metal-troilite intergrowths indicative of post-lithification shock. A few percent of the patches of arcuate troilite in the metal nodules consists of pure troilite cores surrounded by mixtures of ~40 vol.% troilite and ~60 vol.% tiny wormy kamacite grains. The inside edges of some metal nodules contain long (≤2 mm) stringers of fine-grained silicates mixed with troilite. Inside some 40-100-µm-thick metal veins in the matrix there are 10-30-µm-size silicate fragments surrounded by 5-12-µm-thick rinds of fine-grained silicates intimately mixed with metal. The sides of the silicate fragments were torn off and, in some cases, melted.

Although the O-isotopic compositions of Gujba and the other Bencubbin-like meteorites (Bencubbin, Weatherford, QUE94411, Hammadah al Hamra 237) are near those of CR chondrites [3], the Bencubbin-like meteorites (and the CH chondrites) differ from normal carbonaceous chondrites in containing very few (if any) chondrule-like objects with metal grains or porphyritic textures. This mitigates against an origin of Bencubbin-like meteorites and CH chondrites similar to that of normal chondrites. Suggestions for their origin include formation at extremely high temperatures in dust-free regions of the protoplanetary disk [6] and formation by condensation within impact plumes on a chondritic asteroid [7]. The pristine, unweathered nature of Gujba makes it the ideal sample for potentially distinguishing between such nebular and non-nebular models. After formation, the Bencubbin-like meteorites were shocked; some metal and silicate nodules were fragmented, some troilite and metal were melted, and some shock veins were produced.

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