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The Parent Body of a Pallasite Meteorite Based on Relationships among Texture & Mineralogy: Insights into Processes Took Place during Early Stages of the Solar System

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Abstract:- Meteorites are the oldest rocks available for study and record processes that took place during the birth and early history of the Solar System. These rocks are derived from asteroids by cratering collisions, eventually crossing Earth′s orbit to land on the Earth's surface. As a result and unlike terrestrial rocks, the meteorites demonstrate very diverse textures. The orbital relationships between meteorites and asteroids suggest that the interior of the asteroid belt is characterised by parent bodies with an abundance of chondrules. The petrographic study of a meteorite fall was carried out to identify its texture and petrographic sub-type. The meteorite fell in Al-Deyasser village west to Gharyan city, Libya (N: 32º 09 03" – E: 12º 59 02") with total mass of about 100g. A polished thin section of the rock was studied using polarizing light microscope and SEM (scanning electron microscope), it illustrates mixture of chondrules, mm-sized silicate mineral 'droplets', olivine surrounded by a bright silver-colored iron-metal matrix, ~62 vol % of metals (~ Fe and Ni). In addition, carbonate and quartz occur as rare and small crystals within isolated pores that formed during aqueous alteration in the parent bodies of meteorite. Using RTB (Rose-Tschermak- Brezina) scheme the meteorite is being to be related to a sub-group of meteorites called the pallasite meteorites that are rare and very complex meteorites. These meteorites represent mixtures of core and mantle materials that lie on the core-mantle boundary in the interior of the Earth.

Keywords:- *meteorite; pallasite; carbonate minerals.*

I. INTRODUCTION

Meteorites are fragments of asteroid (figure 1a), collisions and eventually fall to Earth. It has also been reported that some meteorites may be derived from the moon and Mars. Meteorites are the oldest rocks available for study and record processes that took place during the birth and early history of the Solar System. As a result and unlike terrestrial rocks, the meteorites demonstrate very diverse textures. A sub-group of meteorites called Pallasites are rare and very complex meteorites, classified into 3 types based on their differences in silicate mineralogy and composition, metal and oxygen isotopic composition. There are three pallasite types that are distinguished by differences in silicate mineralogy and composition, metal, and oxygen isotopic composition: (1) the main group pallasite; (2) the pyroxene pallasite; (3) the Eagle Station grouplet. The main-group pallasites and the Eagle Station grouplet are made up mainly of olivine, with minor amounts of low-Ca pyroxene, chromite, phosphates, troilite, and schreibersite [1]. However, the Eagle Station grouplet has more ferroan and calcium-rich olivine ([1] ; [2]). The pyroxene pallasites characterized by occurrence of millimeter-sized pyroxenes that discriminate the meteorite from main-group and Eagle Station grouplet pallasites (e.g. [3] , [4]). Here we have sought to evaluate the petrographic subtype of a pallasite meteorite that has recently been found in Al-Deyasser village, west to Gharyan city, Libya (N: 32º 09 03" – E: 12º 59 02") with total mass of about 100g (figure 1b). The study has also aimed to characterize terrestrial weathering and the parent body (an asteroid, Moon or Mars?) of the meteorite. Three fragments of the rock were collected by team of geology and geography departments at Gharyan and Alzawia universities. The total mass of these fragments are 100g.

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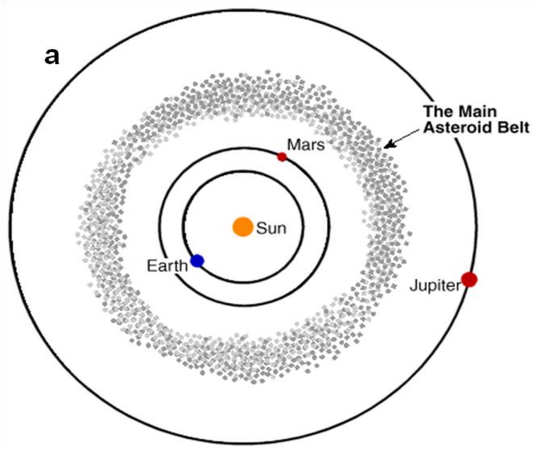

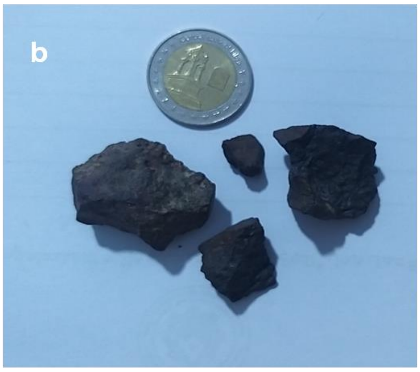

Fig. 1 (a): is illustration shows the orbit of asteroids that probably are the source of meteorites. It has also been reported that some meteorites may be derived from the moon and Mars. b is photograph of the studied meteorite, a fragment was used for thin section preparation, the coin for scale.

II. METHOD

One thin section of the meteorite was prepared by technical staff in the thin-section lab of Libyan Petroleum Institute. The sample was polished briefly in colloidal silica. Several locations were imaged using the JEOL JSM-5510LV Scanning Electron Microscope (SEM) at geological laboratory of the Industrial Research Center, Tripoli.

The backscatter electron (BSE) and secondary electron (SE) imaging were undertaken using BSI detector and SEI, respectively. The images were collected in high vacuum using a 25 keV beam. The step size was set to ±18 µm depending on the size of the area and the scale of the features of interest. The working distance to the beam was 42 mm. Prior to SEM work, the polarizing light microscopy was used to obtain the petrography description of the sample. Materials sized from microns to millimetres were studied in transmitted light using Leica petrological microscope equipped with objectives ranging from x5 to x50. This microscope also allows digital images to be obtained using an Leica icc50E camera X10 operated through cell^B software. For polarising light microscopy a polariser is positioned in the light microscope between a sample and light source and an analyzer is placed between the sample and eyepieces. Bulk porosity is currently measured in meteorites utilizing the following methods: ideal-gas pycnometry, shared with volumetric measurements utilizing either glass beads or X-ray microtomography or 3D laser scanning. Due to lack of these advanced techniques, the camparsion chart for visual percentage estimation [5] was used to estimate the percentage of porosity, veins, matel and other constituents.

III. RESULTS AND DISCUSSION

Using RTB scheme, the meteorite is being to be related to a sub-group of meteorites called the ballasite meteorites that are rare and very complex meteorites. Pallasites are stony irons comprised of approximately equal contents of silicate minerals (mainly olivine), troilite and metal [6]. The studied meteorite has dull black fusion crust covering 60% of its exterior. Cleaving this specimen revealed a fine-grained, grayish-black interior. Hematite deposit is present immediately underneath the fusion crust. The meteorite contains roughly 8% millimetre sized pores, and are present as isolated vug and veins cross cut the matrix. The vugs and veins are partially and totally filled secondary materials (i.e. hematite, carbonate, silicates), respectively (figures 2 and 3). The presence of porosity has important implications for chemical changes in asteroidal materials. As other inchondrites, the pores can facilitate the movement of fluids and during metasomatism that accompanies thermal metamorphism. Subsequent the formation of secondary minerals (e.g. quartz, carbonates, oxides), and as result of elements movement into and out of various meteorite constitutes(silicates and metal) (e.g. [7]).

The petrographic description of this work demonstrate two episodes of crystallisation. The high temperature phase is composed dominantly of olivine with minor of pyroxene and rare amphibole. The grains interlocking boundaries and occur together as a spherical to subspherical 'droplets' or fragments within a size range of 1mm to 4 mm forming, these aggregates are called chondrules (figure 4) that easily characterize meteorites from terrestrial rocks. The rock contains about 25% chondrules Fe-Mg silicates. Chondrules are up to about 2.5 mm across and show a variety of textures including porphyritic olivine (figure 4b), barred olivine and porphyritic olivine and pyroxene (figure 4a). It has about 5% pristine chondrule fragments. The size of chondrule fragments range from a few microns to about 2 mm. Chondrules and chondrule fragments are embedded in a network of metal (probably nickel-iron) (figure2 c, d and figure 3a).

The second phase of crystallization is represented by occurrence quartz, carbonate (i.e. calcite and dolomite and hematite withi**n** fractures, veins, and vugs (figure 2 and 3**)**. Carbonates are widely believed to have crystallized by aqueous alteration within asteroidal parent body(ies) of CM chondrites (subtype of meteorites) (e.g. [8] and [9]). Furthermore, many publications have discussed the petrographic occurrence of carbonate minerals in CM chondrites, and in terms of mineralogy, and chemical and isotopic composition (e.g. [10]; [11]; [12]; [13; [14] ;[15] ;[16;[17] ;[18] ;[19]), and most cunclusions of the previous work are consistent with

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hypothesis that minerals formed at high temperature (e.g. olivine and pyroxene) reacted with water vapor within the solar nebula as the temperature fell to about 375 K. Hematite ($Fe^{3+}{}_2O_3$) and magnetite ($Fe^{2+}Fe^{3+}{}_2O_4$) are iron oxides occur in many meteorites as a terrestrial weathering product (e.g. iron finds) [20]. The studied meteorite is freshly fallen meteorite and rather than lack of rust, it has reddish staining which probably contains hematite, and as the sample collected soon after the meteorite falls, so the rust has probably formed before falling of the meteorite.

Based on the meteorite petrography and quantifying porosity in primitive achondritic primitive materials, [21] and [22] have concluded that Pallasites are likely to be produced from the deep interiors of asteroidal parent bodies, from the boundaries of core-mantle, where olivine beds crystallized with mantle differentiation would have adjacently settled to the iron core. Therefore the studied meteorite can be classified as a unique sample that record processes occurred during early history of the solar system. Thus, a suite of analytical instruments (SEM, EPMA, SIMS & TEM) are required to build up a coherent picture about the evolution of parent body of the studied meteorite.

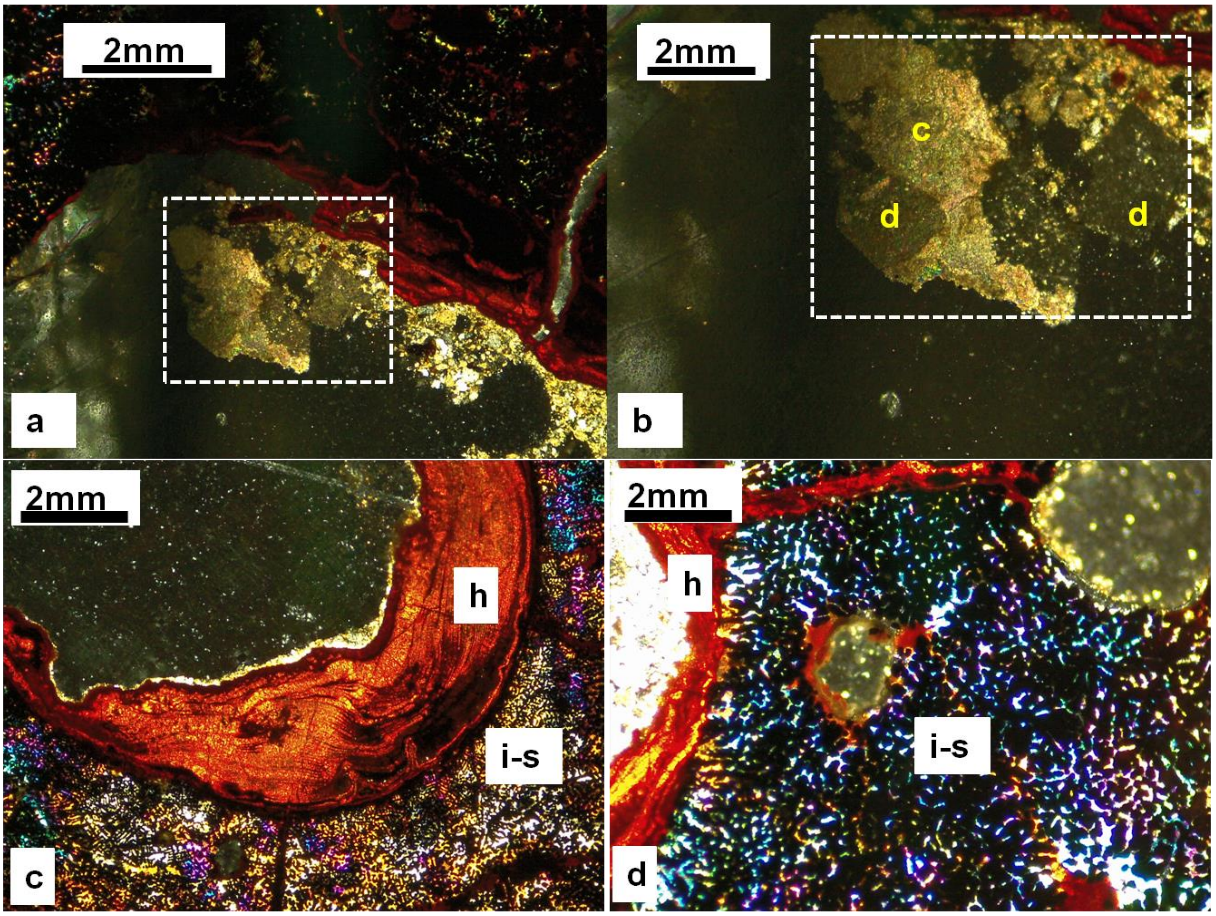

Fig. 2: Photomicrographs of thin section under transmitted light and between crossed polarisers. The images display the meteorite contents, square in a shows carbonates, X5 objective was used. Square in b specify carbonates: c is calcite and d is dolomite, X10 objective was used. c and d show intergrowth olivine with metal (Fe-Ni) that is represented by i-s, metal is opaque, h is hematite filled fractures cross-cut the sample and appears reddish under the transmitted light XPL. X5 objective was used in c and X10 objective was used in d.

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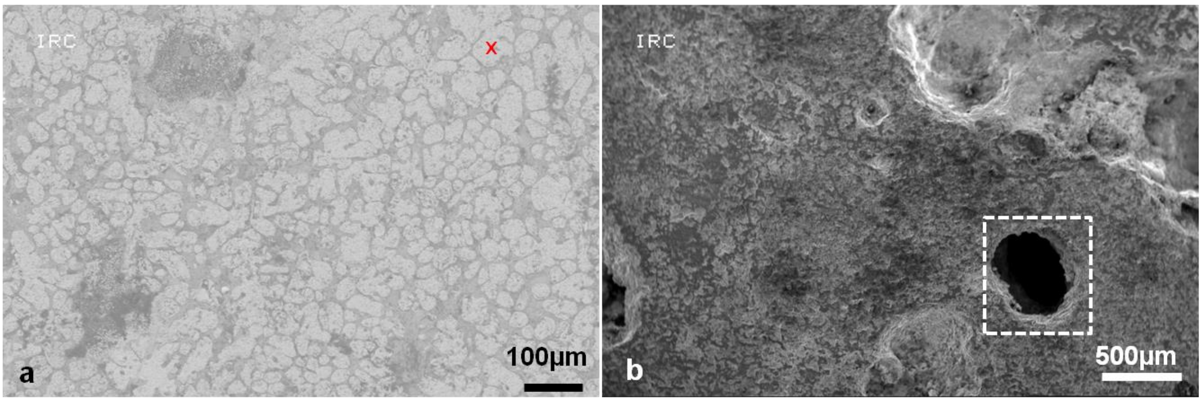

Fig. 3: SEM images. a is BSE image of Fe-Ni metal (bright areas) in the meteorite (x is an example of matel appearances) and silicates appear as grayish areas that intergrowth with metal. b is SE image of the hand specimen of the meteorite shows the occurrence of vugs, squared area.

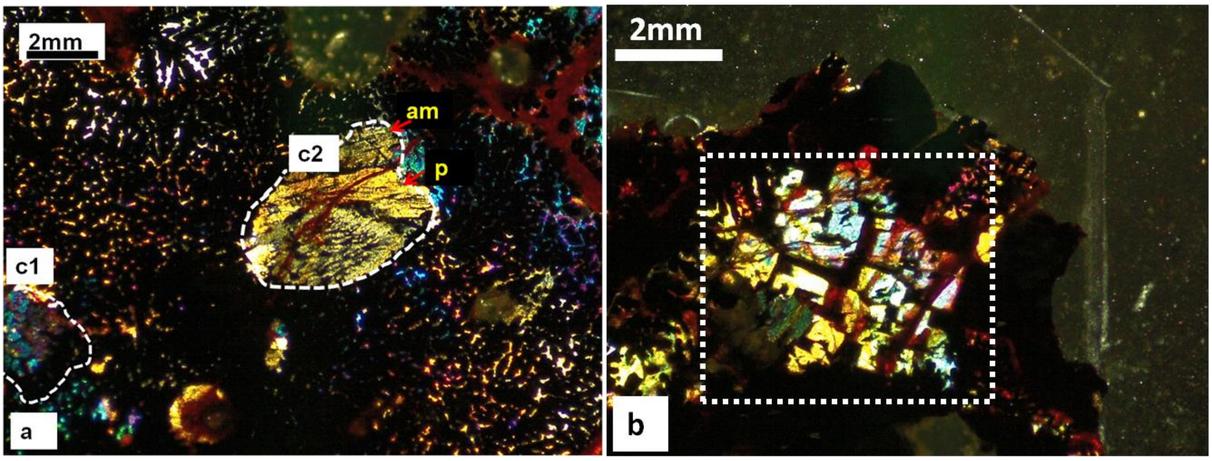

Fig. 4: Photomicrographs of thin section under transmitted light and between crossed polarisers. The images display two types of chondrules, detached circles (c1&c2) in a shows porphyritic pyroxene chondrule, am is amphibole and p is pyroxene. Square in b showing a porphyritic olivine chondrule with euhedral and subhedral olivine crystals and sharp edges

IV. CONCLUSION

The studied meteorite is meteorite falls and is classified as unique sample, as it derived from the deep interiors of asteroidal parent bodies, from areas that are mainly composed of mixture of iron and olivine. These areas are equivalent to the boundaries of core-mantle of the Earth. The meteorite is pallasite meteorite contains mixture of metal and silicates (i.e. olivine and pyroxene) that formed under high temperature conditions, and contains accessories minerals including oxides (hematite and magnetite), quartz and carbonates (i.e. calcite and dolomite) that were formed by water action and probably prior to its falling as it was observed and instantaneously collected.

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