# CATCHING CONSTRAINTS ON THE PARENT BODY GENESIS OF MESOSIDERITES AND A POSSIBLE LINK TO HED (HOWARDITE-EUCRITE-DIOGENITE) METEORITES – A NEW HOPE?

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## 1) MESOSIDERITE (MES) MYSTERY:

- Enigmatic stony-iron meteorites & fragmental matrix breccias with irregular textures [1,2; Table 1].
- Roughly equal volumes of metal (Fe-Ni) and silicates -> strongly mixed.
- Silicates: consist of basaltic, gabbroic, and pyroxenitic components = ± Eucrites/Howardites [3-8].
- Silicates = strongly metamorphosed after formation = difficult to assess their origin.

⇨ Hence, tough assessment of MES parent body differentiation process [9,10].

- MES silicates = **LIKELY** an origin and residence at the surface of a differentiated body [11],
- **BUT!** Slow cooling rate of the metal points to an origin in the deep interior [12].
- ➢ Possible EXPLANATIONS?
  - ✓ 1st: Large impacts and re-assembly of multiple precursor bodies - whether of differentiated or primitive origin - as the main cause for silicate/metal-mixing [e.g. 1,2].
  - ✓ 2nd: Mixing of near-surface silicates with the interior core-metal on a single parent body, by an event such as a catastrophic breakup [e.g. 11].
- FOLLOWED BY: a) 2nd mixing events - b) surface brecciation - c) deep material burial + slow cooling d) remelting and/or metamorphosis.

## 2) MOTIVATION:

- ○ Most published metallographic cooling rates on MES, of ~0.05 - 0.2 K/Ma, are slower than might be expected given the rapid nature of impact or breakup events; e.g. [10,13-15].
- ○ [16] discuss: Relatively slow metallographic cooling rates of MES are in agreement with slow cooling of a large parent body to the closure temperature of Ar ~4 Ga ago = the age of many silicate inclusions.
- ○ This raises the question of whether the Ar-Ar ages result from cooling on their original parent body, the MES mixing event, or later impacts.
- ○ Previous studies often analyzed the Type 1A meteorite Vaca Muerta [17-19] = large silicate inclusions + least recrystallized.
- ○ Many attempts focused either on silicates or metals, but not both.
- ○ Noble gases: The compilation of [20] show He to Ar data on 23 MES - BUT it is lacking on Kr and Xe data. [21] report 37 MES in 2014 which makes new measurements possible and necessary.

## 3) SAMPLE-SELECTION AND CLAST ASSESSMENT IN CROSSED POLAR LIGHT

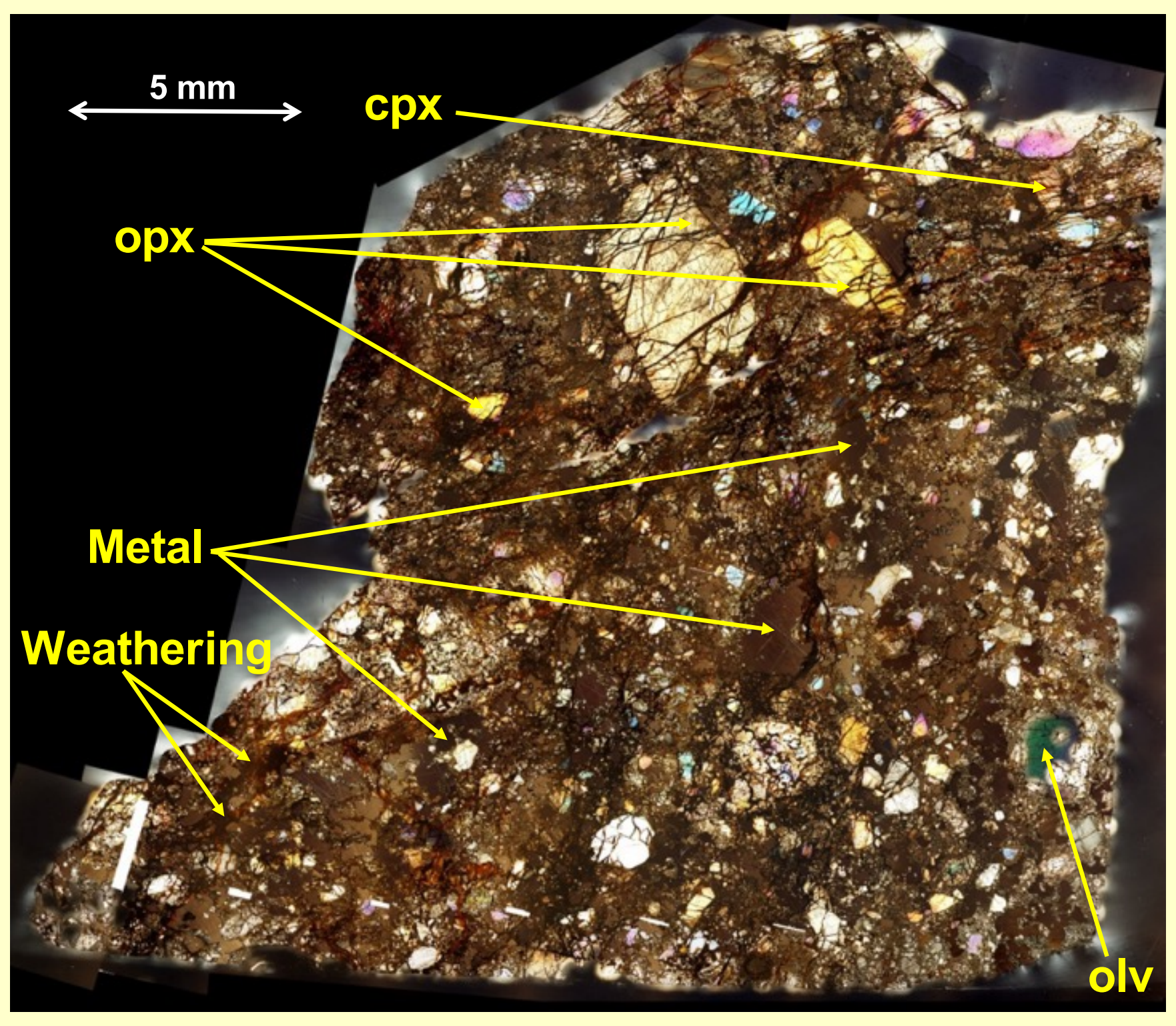


Fig. 1. Mount Padbury – Type 1A

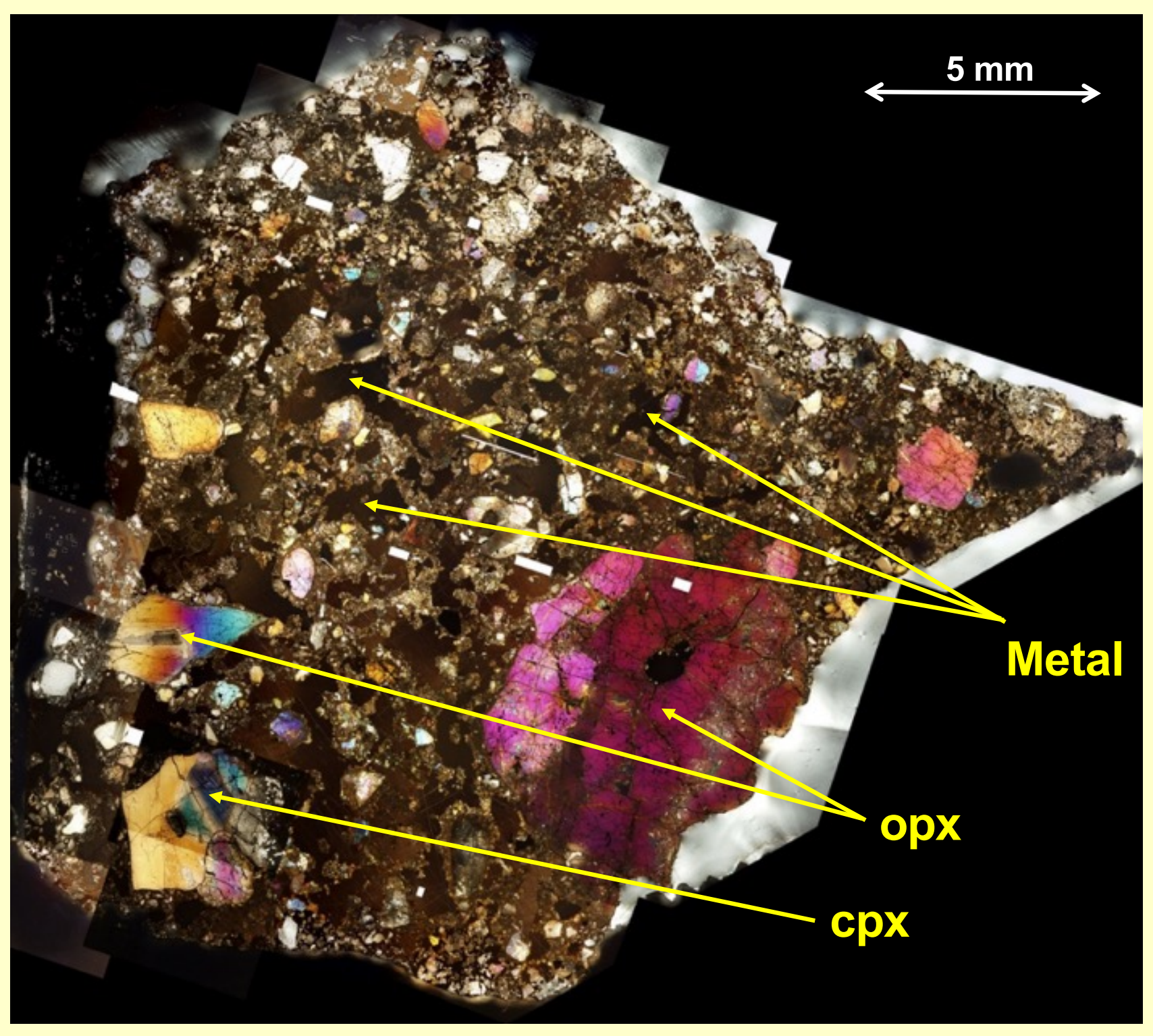


Fig. 2. Patwar – Type 1A

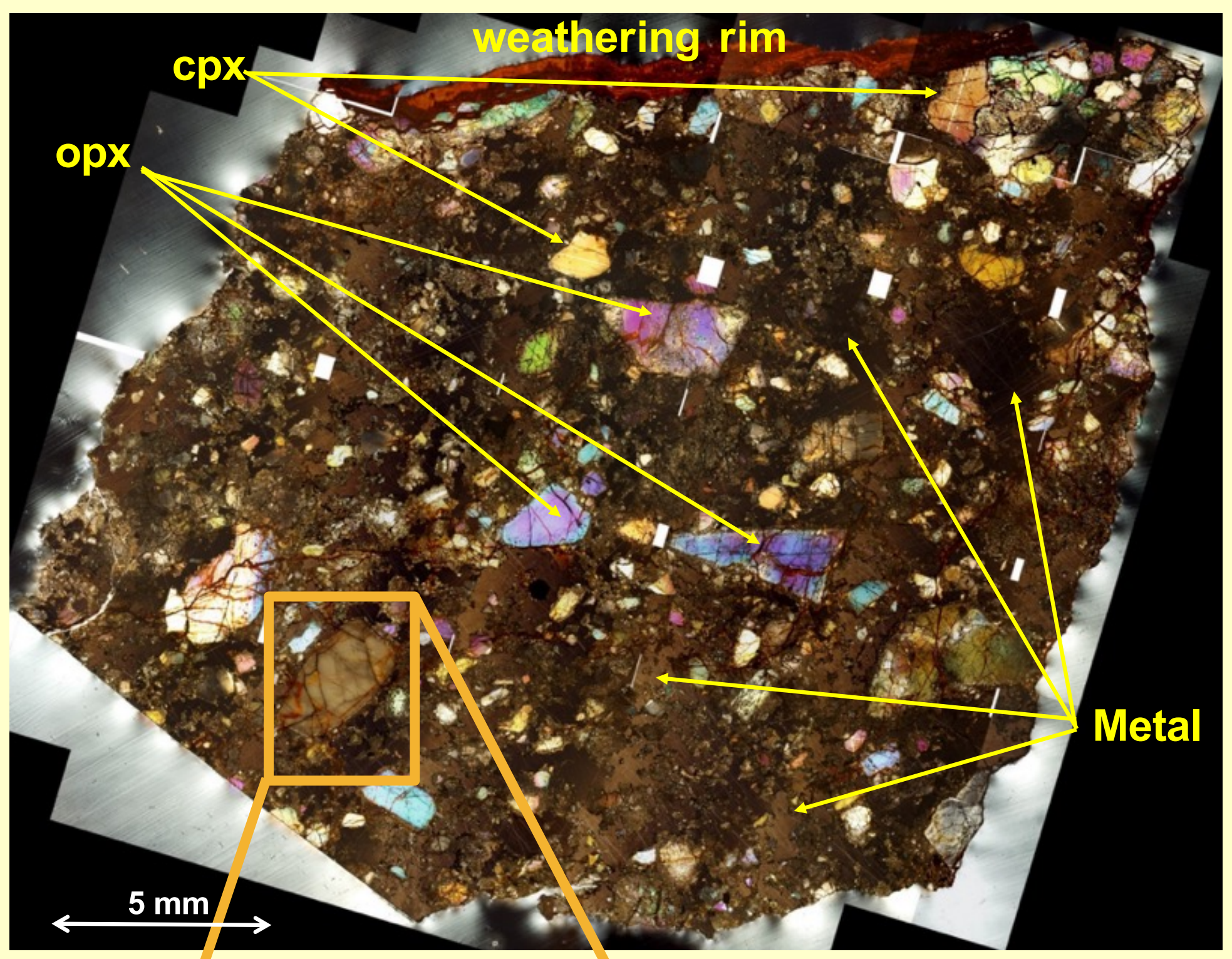


Fig. 3. Crab Orchard – Type 1A

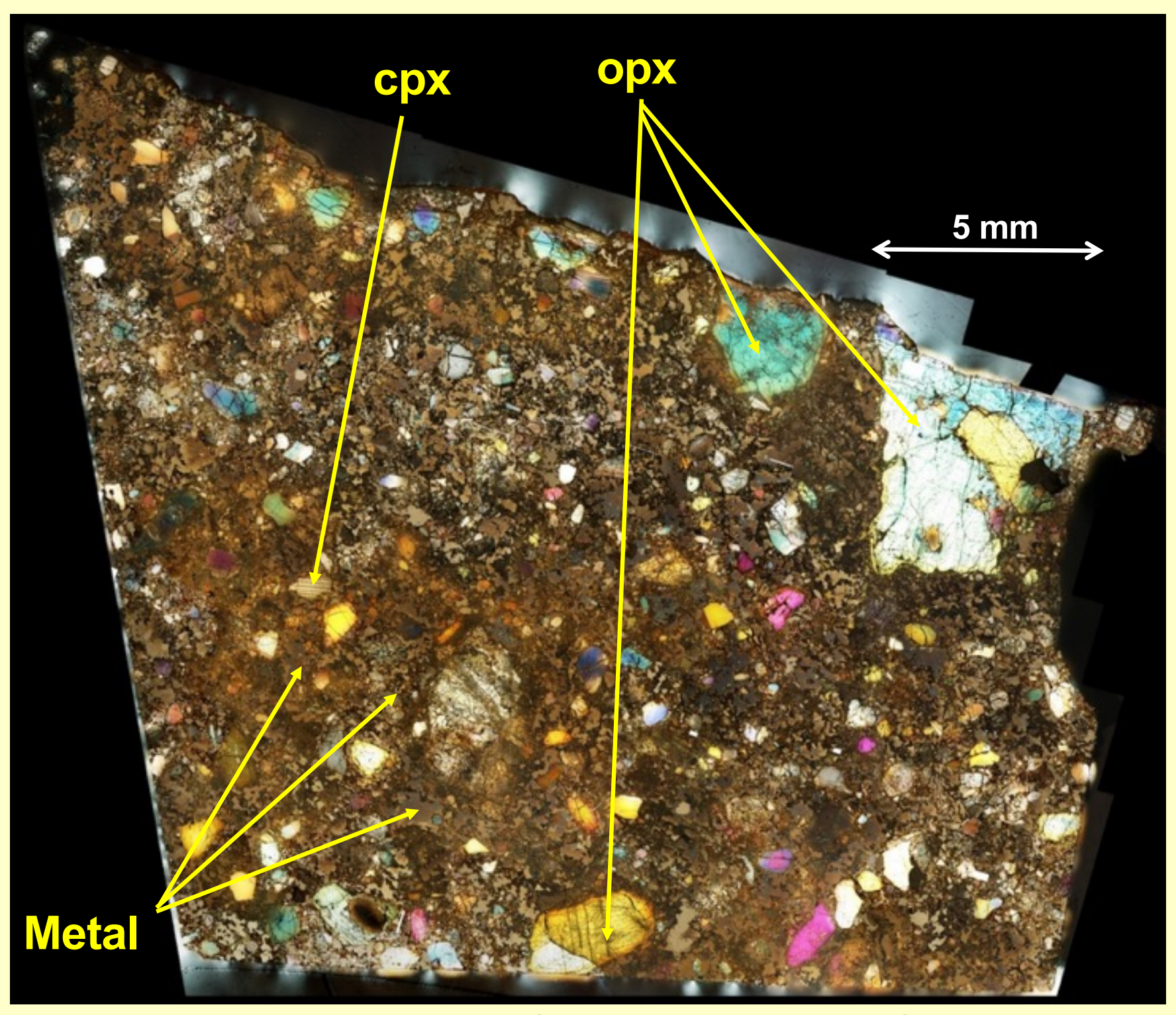
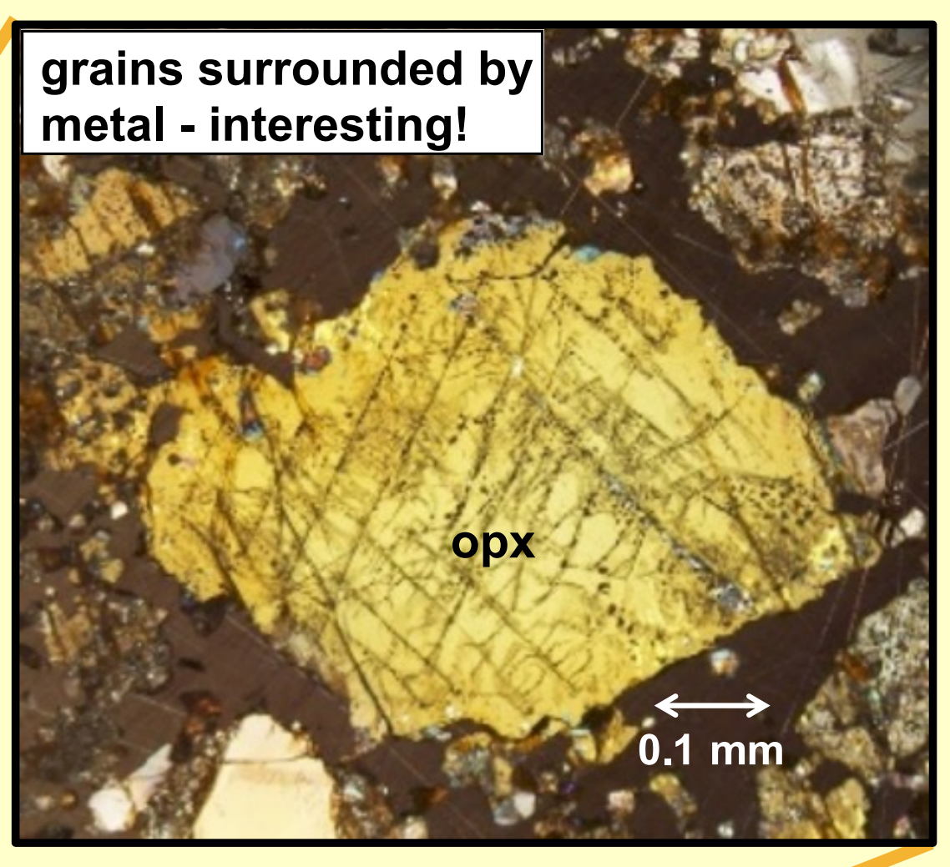


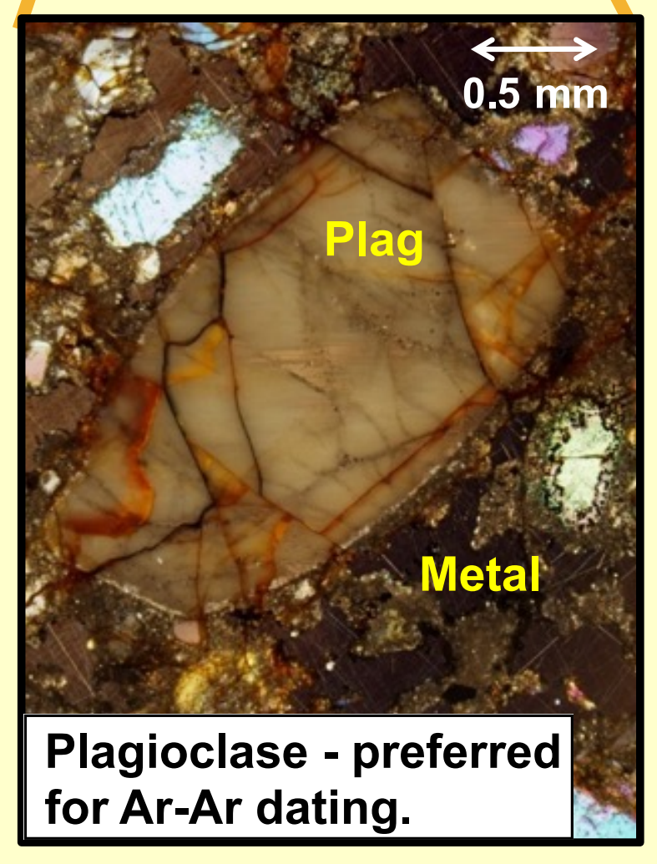
Fig. 4. NWA 1242 – Type 2A, S1, W0, resorption of Plagioclase

Table 1. Classification of (some) well known mesosiderites (after [22] and references therein). Type A = similar Howardites; Type B = similar Diogenites/Cumulate Eucrites

| | recrystallized matrix | | | melt matrix / igneous / plag-POIK | |
|---|---|---|---|---|---|
| | 1 (little) | 2 (moderate) | 3 (high) | 3/4 | 4 |
| **Type A** | **Crab Orchard**<br>**Mount Padbury**<br>**Patwar**<br>Vaca Muerta | **Clover Springs** | Emery<br>Lowicz<br>Morristown<br>West Point | Estherville | Hainholz<br>Simondium |
| **Type B** | ALHA 77219<br>Chinguetti | Veramin# - - -<br>RKPA 80258# - - | **Bondoc#**<br>Budulan#<br>Pinaroo# | - - - - - - → | # |

# - Reclassified by [22] due to plagioclase-POIK (poikilitic) melt matrix.





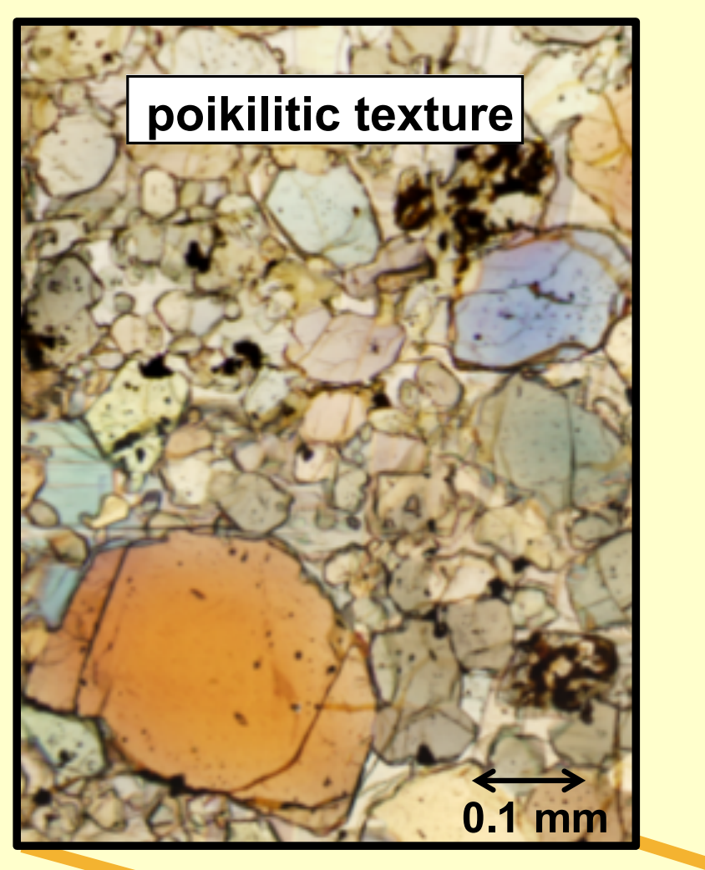


Table 2. Typical modal composition [%] of minerals in Type A & B MES (after [22] and references therein).

| Mineral | Type A | Type B |
|---|---|---|
| Orthopyroxene (opx) | **55.1 (5.5)** | **75.6 (4.9)** |
| Clinopyroxene (cpx) | 2.8 (1.5) | 1.1 (1.1) |
| Plagioclase (Plag) | **29.3 (8.4)** | **16.7 (3.7)** |
| Olivine (olv) | 1.9 (1.5) | 2.2 (2.3) |
| Tridymite | 6.2 (2.3) | 2.0 (1.6) |
| Phosphate | 2.2 (1.0) | 1.2 (0.6) |
| Chromite | 0.7 (0.5) | 1.3 (0.4) |

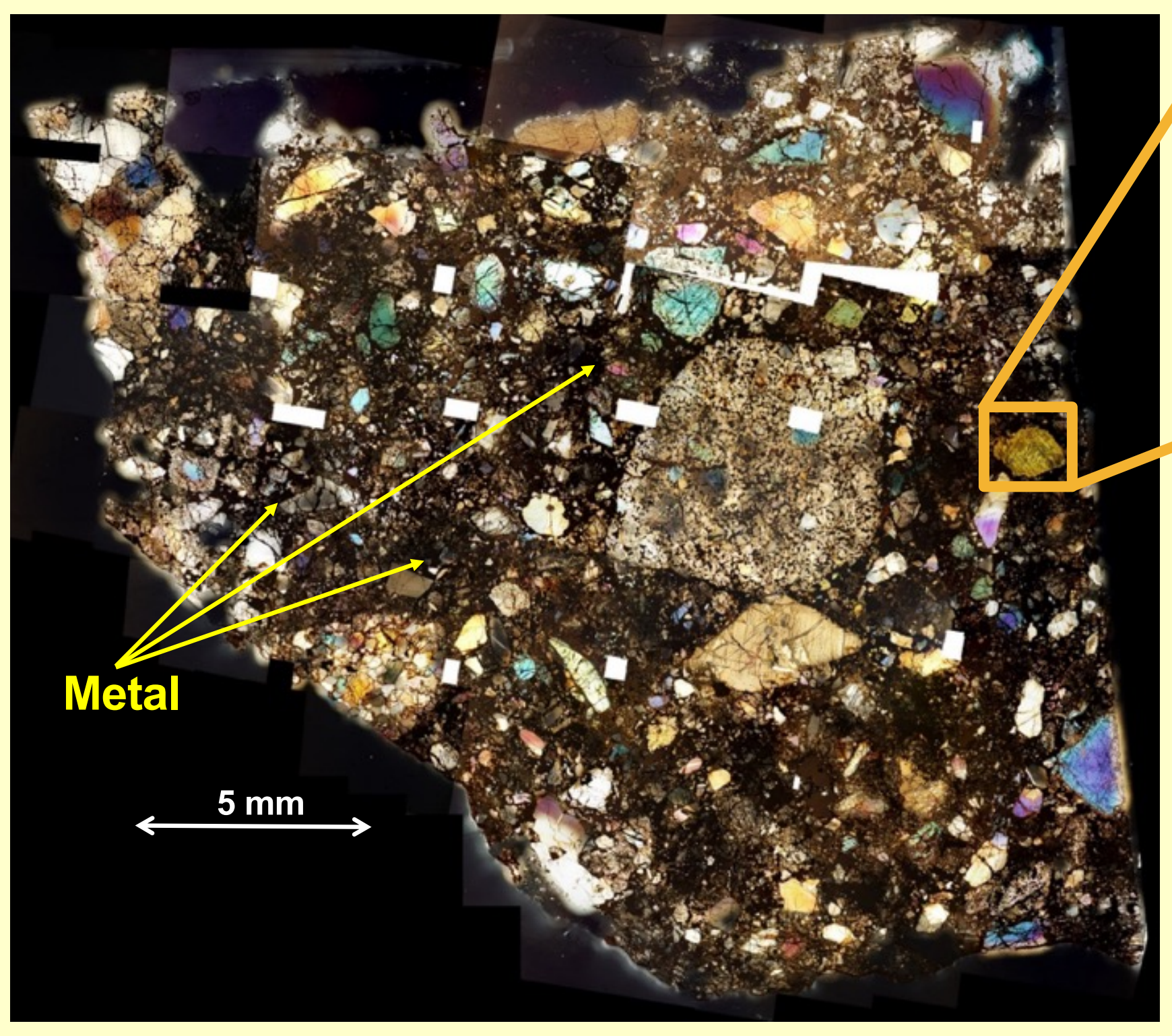


Fig. 5. Clover Springs – Type 2A

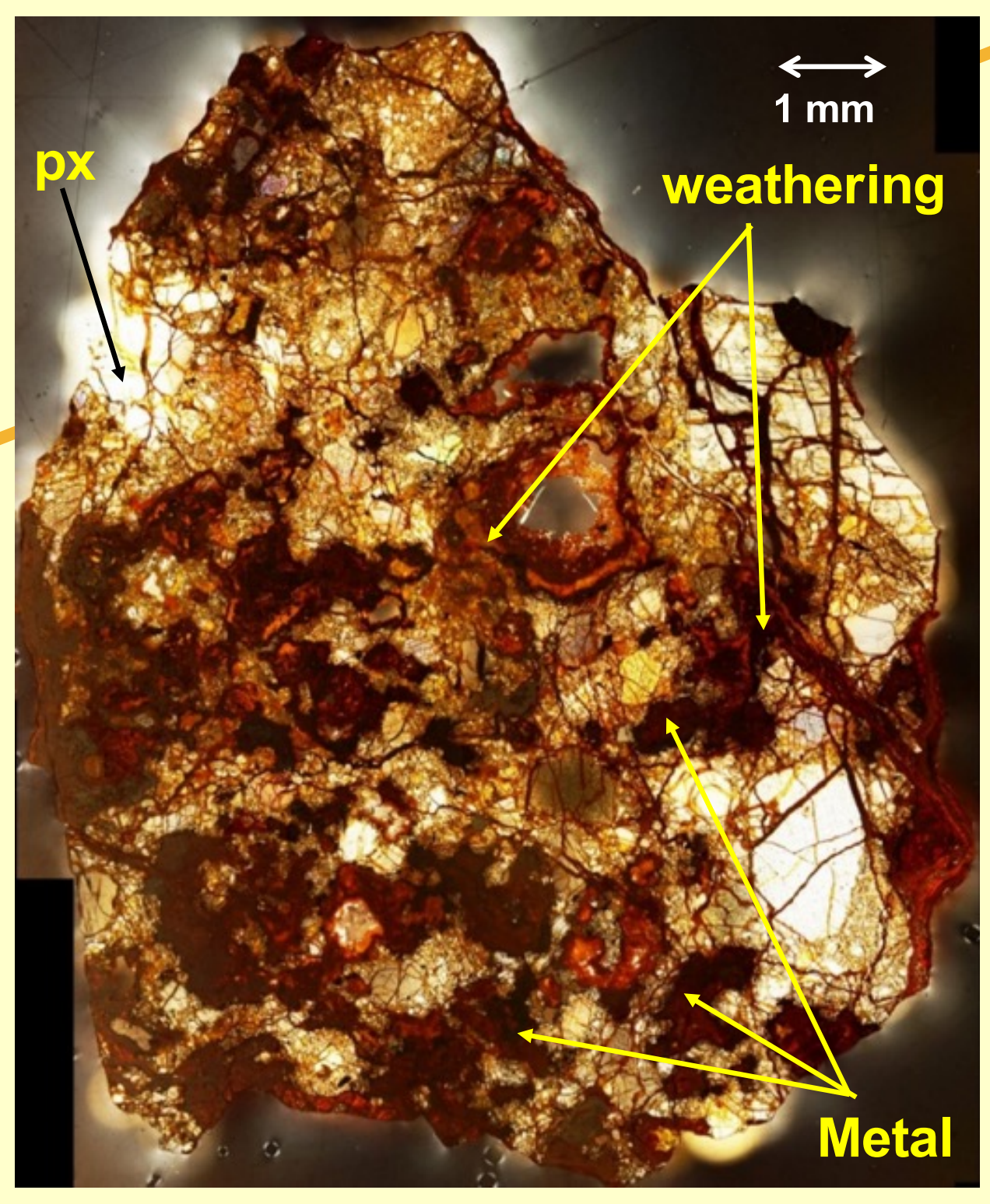


Fig. 6. NWA 8561 – Type 1A

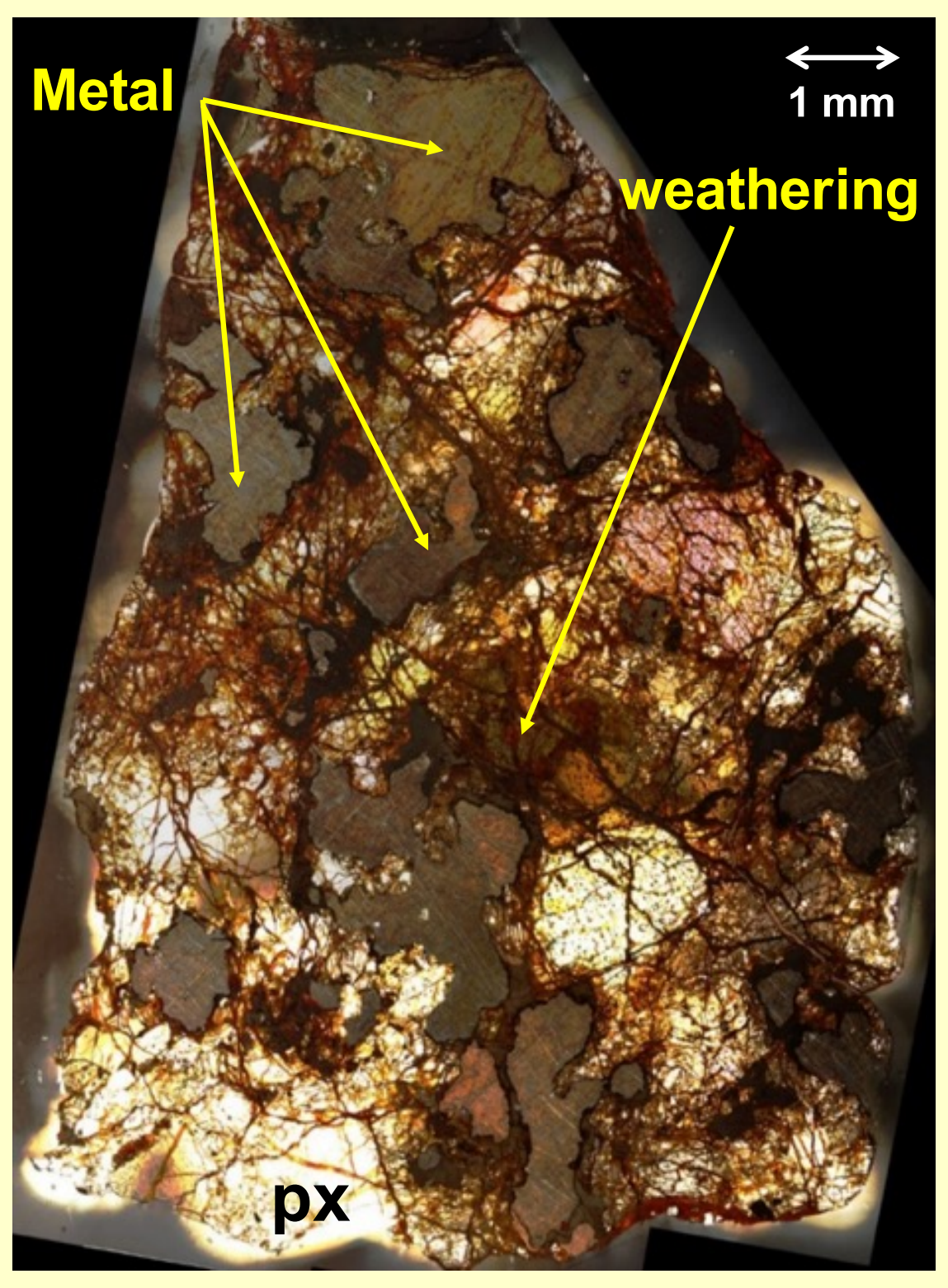


Fig. 7. Toufassour – Type 1A

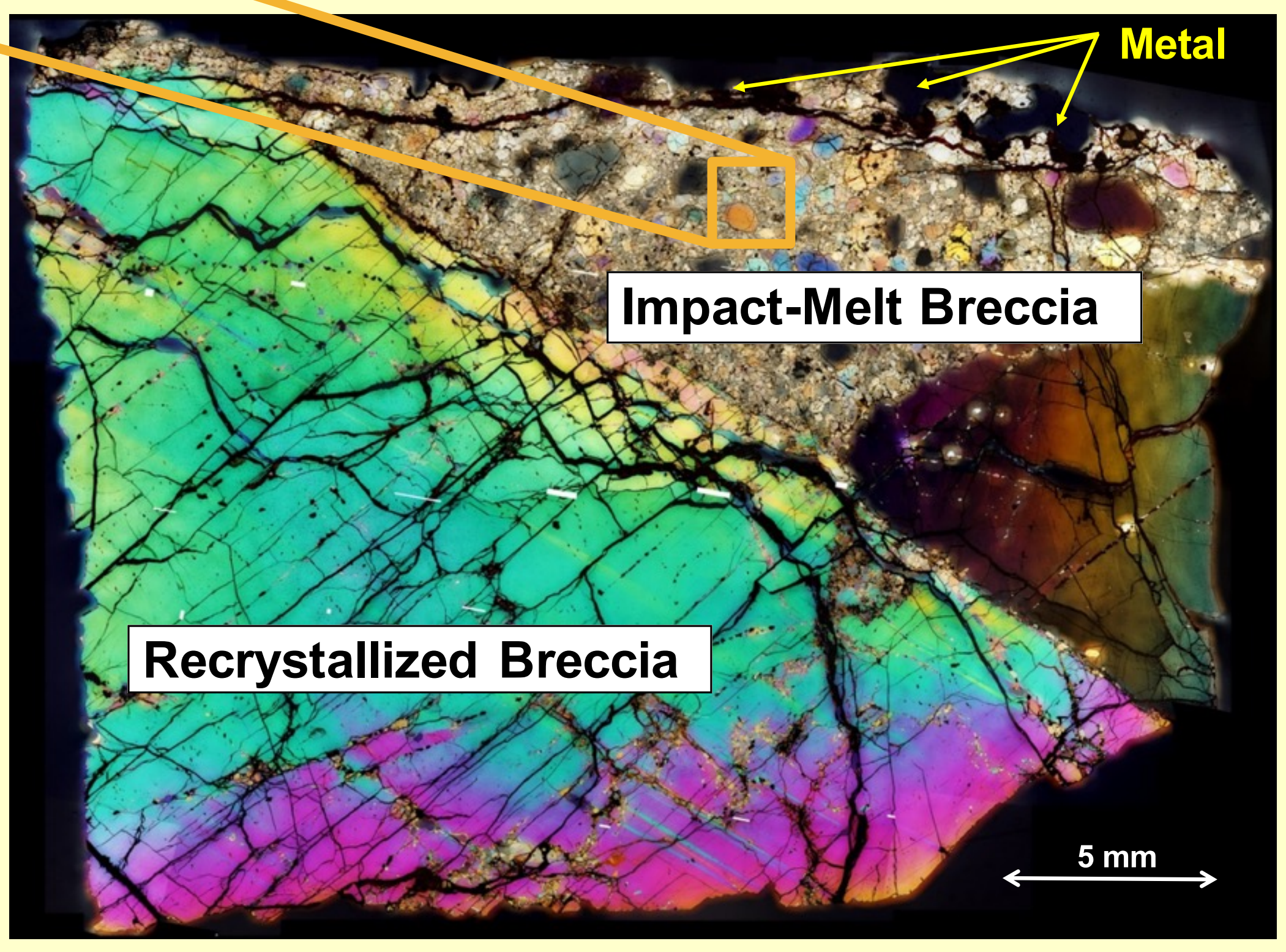


Fig. 9. Bondoc – Type 3B (reclassified by [22] to Type 4B)

## 4) GOALS AND EXPECTATIONS:

Reveal the history of the mesosiderites by combining different methods for an integrated approach.

- ➢ Understand the MES silicate mineralogy by analyzing petrography and composition.
- ➢ Measure MES noble gas inventories to understand both their origin and burial history:
  - ▪ Most MES probably show an achondritic noble gas signature, but if some retain a chondritic noble gas inventory, we can infer an impacting body was responsible for contributing primitive material.
  - ▪ Deficiencies in primordial abundances might link burial depth to equilibration temperatures, especially for Type A1 to A2 MES [23].
  - ▪ Linking $^{40}$Ar-$^{39}$Ar ages to metallographic cooling rates may determine when both components cooled together.
  - ▪ Post-accretion metamorphosis, recrystallization and terrestrial weathering should be observable as depletions in the noble gases, particularly He and Ne.
  - ▪ We expect large Ne-cos, Ar-cos & Xe-cos contributions of clasts spent long time near the surface.
- ➢ Compare MES with groups of differentiated meteorites similar in mineralogy, texture and possible formation history; i.e. HEDs, anomalous and silicate bearing iron meteorites e.g. [4,7].
- ➢ Examine MES rare-earth-element (REE) values in numerous gabbroid melt clasts – particularly positive Eu [4,18] – and contrast them to HEDs, which do not show the same. Even if the HEDs and MES were not formed in the same parent body, the processes that created them may reflect similar processes on differentiated bodies.

## 5) FUTURE WORK:

- ✓ Select the least recrystallized clasts in our MES (Table 2; Fig.1-8) to perform studies on the differences between silicate and metal chronology, as well as the noble-gas inventory of these clasts as clues to their origin.
- ✓ We will search MES samples for clasts that consists of ortho-/ clinopyroxene and plagioclase that appear to be co-genetic to metal blebs.
- ✓ Characterize composition of clasts using stereo-microscopy, SEM and e-probe along with calculating metallographic cooling rates.
- ✓ Analyze the noble-gas complement (He- Xe) of the silicate inclusions and assess Ar-Ar and cosmic-ray exposure ages using the MSFC state-of-the-art Noblesse (Nu Instruments, UK) MS = new high sensitivity + multi-ion-detection.
- ✓ Measure the metallographic cooling rates and compare them to Ar-Ar ages for each clast; if these agree within single clasts, we can infer closure temperatures connected to the burial depth.
- ✓ If material allows, we will then measure Sm, Yb and Eu in the clasts to compare with HEDs.

References: [1] Powell B. N. (1971) GCA, 35:5-34. [2] Floran R. J. (1978) Proc. Lunar Planet. Sci. Conf. 9th, 1053-1081. [3] McCall G. J. H. (1966) Mineral. Mag.,35:1029-1060. [4] Mittlefehldt D. W. et al. (1979) GCA, 43:673-688. [5] Ikeda Y. et al. (1990) Ant. Met. Res., 3:99. [6] Kimura M. et al. (1991) Ant. Met. Res., 4:263. [7] Rubin A. E. and Mittlefehldt D. W. (1992) GCA, 56:827-840. [8] Mittlefehldt D. W. (2014) 77th Ann. Met. Soc. Meeting (Abs. #5313). [9] Crozaz G. and Tasker D. R. (1981) GCA, 45:2037-2046. [10] Keil K. et al. (1994) Plan. Space Sci., 42:1109-1122. [11] Delaney J. S. (1983) Meteoritics, 18:289-290. [12] Bogard D. D. et al.(1990) GCA, 54:2549-2564. [13] Wasson J. T. and Hoppe P. (2014) 77th Ann. Met. Soc. Meeting (Abs. #5405). [14] Hopfe W. D. and Goldstein J. I. (2001) MAPS, 36:135-154. [15] Goldstein J. I. et al. (2009) Chemie der Erde-Geochem., 69:293-325. [16] Haack H. et al. (1992) GCA, 60:2609-2619. [17] Wadhwa M. et al. (2003) GCA, 67:5047-5069. [18] Mittlefehldt D. W. et al. (1992) Science, 257:1096-1099. [19] Bajo K. and Nagao K. (2011) MAPS, 46:556-573. [20] Schultz L. and Franke L. (2004) MAPS, 39:1889-1890. [21] Corrigan C. M. et al. (2014) 35 Seas. of US Antsmet (1976-2010): A Pictorial Guide to the Coll., 173-187. [22] Hewins R. H. (1984) In LPSC Proc. Vol. 15: J. Geophy. Res: Solid Earth, 89(S01): C289-C297.[23] Hewins R. H. (1983) J. Geophy. Res.: Solid Earth, 88(S01):B257-B266.

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