Chondrites and Chondrules Analogous to Sediments

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51st Annual Lunar and Planetary Science Conference
Houston, Texas
March 16-20, 2020

Introduction and Summary

- Comparing chondrites and terrestrial conglomerates [1] continues
- Meteorites are fragmental rocks, continually subjected to impacts and collisions, whatever their ultimate origin in space and time
- Space outside Earth's atmosphere may be considered a 4D debris field
- Of the debris that reaches the surface of Earth and is available for study, > 80 % are chondrites
- Chondrites and chondrules are generally considered the product of heating of dust in the early Solar System, and therefore effectively igneous in origin
- Modelling these abundant and important space rocks as analogous to terrestrial detrital sediments, specifically conglomerates, is innovative, can help derive data on their true origins and history, and provide con text for ongoing analyses

Chondrites and Chondrules

- Chondrites are rocks made of rocks
- They are composed of chondrules and chondrule-like objects from which they take their name
- Chondrules are roughly spheroidal pebble-like rocks predominantly composed of olivine, pyroxene, feldspar, iron-nickel minerals, chromite, magnetite, sulphides etc.
- They range from nanoscale to more than a centimetre, with some size variation by chondrite type. There are thousands/millions of them available for study
- Hundreds of chondrules fill the area of a single 3.5 x 2.5 cm standard thin section

What is Known ?

- Adjacent chondrules may be millions of years different in age
- They date from the time of earliest solar system objects (viz. other rocks, other agglomerations of minerals such as CAIs)
- Chondrites and chondrules contain relict mineral phases from the interstellar medium (ISM): inorganic and, in some cases, organic materials older than our solar system, perhaps older than our galaxy [2]

Why Study ?

- Each chondrule has witnessed extraterrestrial processes, probably repeatedly
- Minerals in meteorites, their textures, and the elements which form them, may have been formed and re-formed in and around stars reaching back to the origin of the universe
- It makes sense to examine them in as much detail as possible, and to preserve the results for future study

Too Complex ?

- Some have deemed chondritic textures too complex to decipher, but have broadly pigeon-holed them anyway, thus dealing with them without really dealing with them
- Textures are commonly destroyed by grinding up the meteorites to analyze their collective isotopes
- Or, isotopic and other chemical studies neglect to examine chondrule mineralogy and textures

Provenance 1

- On Earth, provenance is the reconstruction of the origin of sediments
- Earth rocks (sedimentary, igneous and metamorphic) erode into sediments at the surface
- Sediments are therefore expected to be able to provided evidence of the erosional history of their parent source rocks

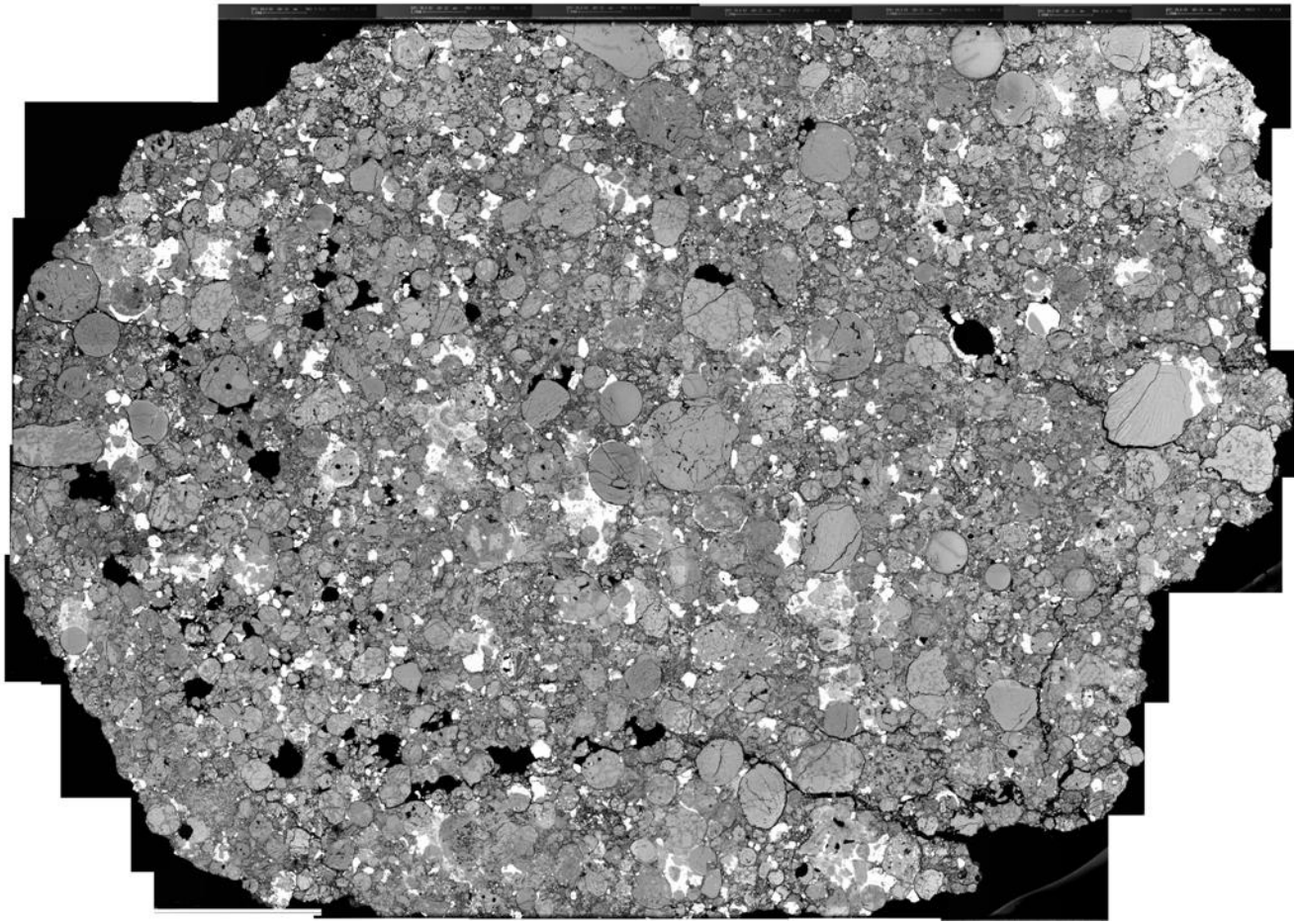
Provenance 2

- “Sediment provenance” specifically refers to the application of compositional analyses to determine the origin of sediments
- The aim is to characterize the “source to sink” journey of clastic sediments from hinterland(s) to sedimentary basin(s), and to reconstruct sources along the way [3]
- Siliciclastic sediments such as sandstones and conglomerates are considered sinks and particularly amenable to provenance analysis

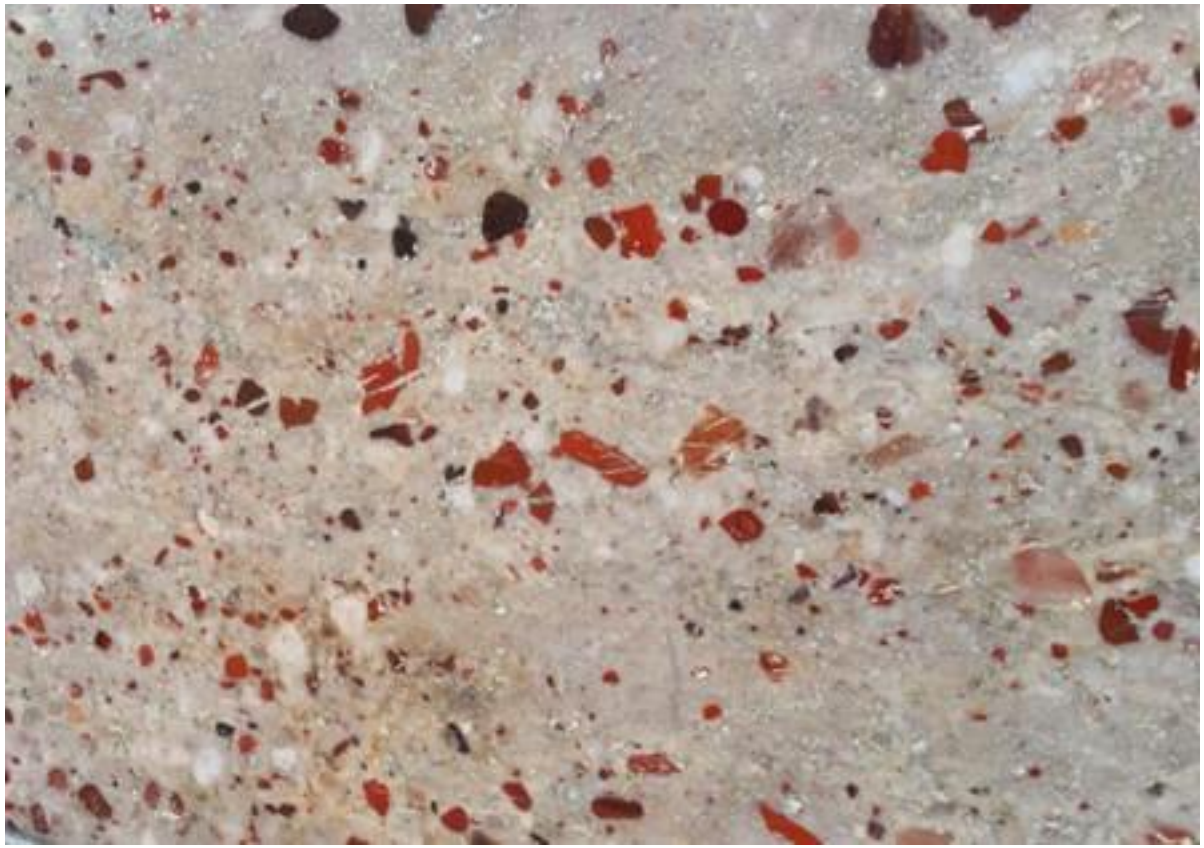
If “A” then “B” then “C”…

- If chondrites resemble terrestrial (sandstones and) conglomerates by being rocks made of rocks, with similarities to sediment sinks (not just random aggregates or agglomerations) then:
- Chondrites and chondrules are amenable to provenance studies
- Chondrites and chondrules are able to provide evidence of the history of their parent source rocks
- A “source to sink” journey or flow chart is discernable for chondrites and chondrules
- The “hinterland” for chondrites and chondrules is the debris field of space rocks, representing rock and mineral forming processes since before the beginning of our Solar System
- The sedimentary basin “sink” is represented by the meteorite sample that fell to Earth and is available for study

BSE Mosaic Saratov L4



Analogue of a Chondrite



Captions

- The BSE image photomosaic is 3.5 x 2.5 cm. The largest chondrules are about 1 mm. in diameter. At this scale perfectly whole/round chondrules and fragmented ones may be seen, as well as the polymict and clast-supported nature of the assemblage. Matrix is present
- The colour photo of the Bruce Conglomerate is about 40 cm across with red, white, and black pebbles about 1-2 cm across in a quartzite matrix

Methodology 1

- There are no textbooks to assist the documentation and interpretation of chondrite and chondrule textures
- Studies over the last decade especially have concentrated on the documentation of intrachondrule and interchondrule textures in grades 3-5 ordinary chondrites using BSE and digital photography
- Hundreds of chondrules in their chondrite matrices have been examined, some repeatedly

Provenance 3

- Understanding that chondrites and chondrules can be subject to provenance analysis like conglomerates and their pebbles opens up new approaches to chondrite and chondrule petrography and petrology
- The textural analyses utilized previously can be put in context

Descriptive Approach

- Obtain BSE imagery of chondrules and their host chondrites, other photos
- Make a preliminary note on the characteristics of the chondrules and their relation to their host. Cf. caption above for Saratov
- Adopt a grid system to locate each chondrule studied (x, y co-ordinates)
- Make a preliminary exploration of the chondrules noting their location
- Choose both archetypical and atypical chondrules for more detailed study
- Obtain detailed BSE imagery of any chondrules chosen
- Assign them to a major standard chondrule group, PO, POP, PP, R etc. [4] noting if they are whole (w), abraded (a), indented (i), fragmented (f) and/or sectoral (s)

Textural Interpretation 1

- Chondrule-forming events are a datum in chondrites, part of a progression
- A flow of events, and processing, is implied and likely, before and after chondrule formation
- Subdivide overall chondrule mineral textures (ω) into those associated with relics (α), derivation by heating/cooling before incorporation into a solid body (β), during formation (β1) and transport prior to incorporation (β2), after incorporation (γ), during (hydrous) weathering (δ), during space weathering (ε) , during fusion crust formation, (π), shock (σ) etc. .

Textural Interpretation 2

- Chondrule textures document more than single events
- melting, heating, cooling, crystallization and reactions have repeatedly occurred
- Four relative grain-sizes of material are contained in chondrules: mega (M), macro (m), micro (μ), and mesostasis (*ms*)
- Subdivide the intrachondrule mineral assemblages by relative grain size
- Derive barcode-like numerical labels for chondrules to associate and/or distinguish them [5,6,7,8]

Methodology 2

- Re-assess the preliminary notes on the chondrite and chondrules after detailed descriptions and textural analysis
- Select minerals for chemical or isotopic analysis, other appropriate and available methods, based on the detailed textural analyses, preserving the samples for future use and interpretation in the light of new results

Block Model

- Consider a block diagram of eroding dendritic stream systems, like a river valley starting at a glacial cirque, water and sediments ending in a delta
- Deltaic deposits theoretically sample and preserve material from all upstream sources
- cf. Mars 2020 Jezero crater edge delta site to maximize sample variety [9] based on surrounding geology
- For chondrites, a single chondrule is like a pebble eroded from a hinterland source, swept downstream, preserving evidence of its origins and journey in its texture and shape, then deposited to become part of a rock again

References

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