

More than a trace of oxygen: Ichnological constraints on the formation of the giant Zn-Pb-Ag±Ba deposits, Red Dog District, Alaska

Merilie A. Reynolds, Murray K. Gingras, Sarah A. Gleeson, and James U. Stemler

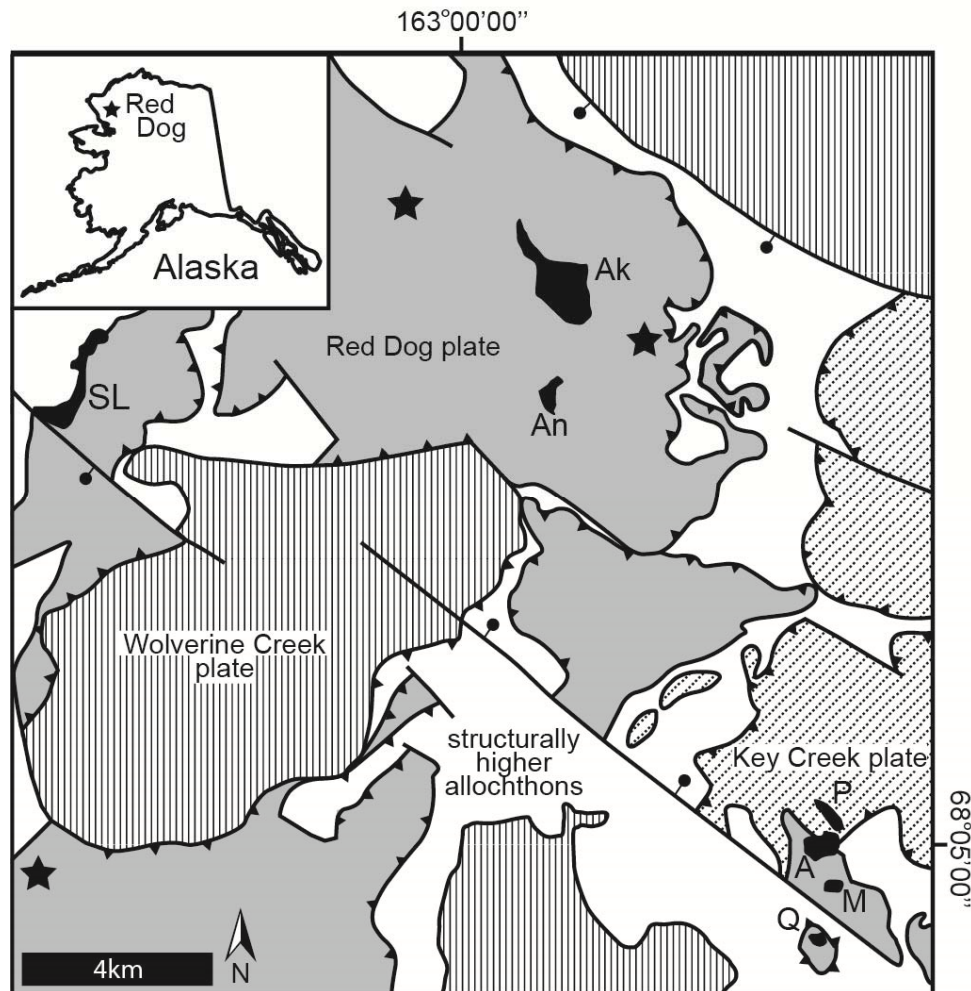


Figure DR1. Simplified map of structural plates of the Endicott Mountain allochthon. The Kuna Fm. occurs in all structural plates of the Endicott's Mountains allochthon but only hosts Zn-Pb mineralization in the Red Dog plate. The Red Dog District Mine Area includes the Main (M), Aqqaluk (A), Paalaaq (P), and Qanaiyaq (Q) deposits. Other known mineralization occurs in the Anarraaq (An), Su-Lik (SL), and Aktigiruk (Ak) deposits and in several other prospects (stars). Surface projections of deposits are delineated in solid black. The nature of some contacts are unknown. Modified after Fig. 2 in Blevings et al. (2013).

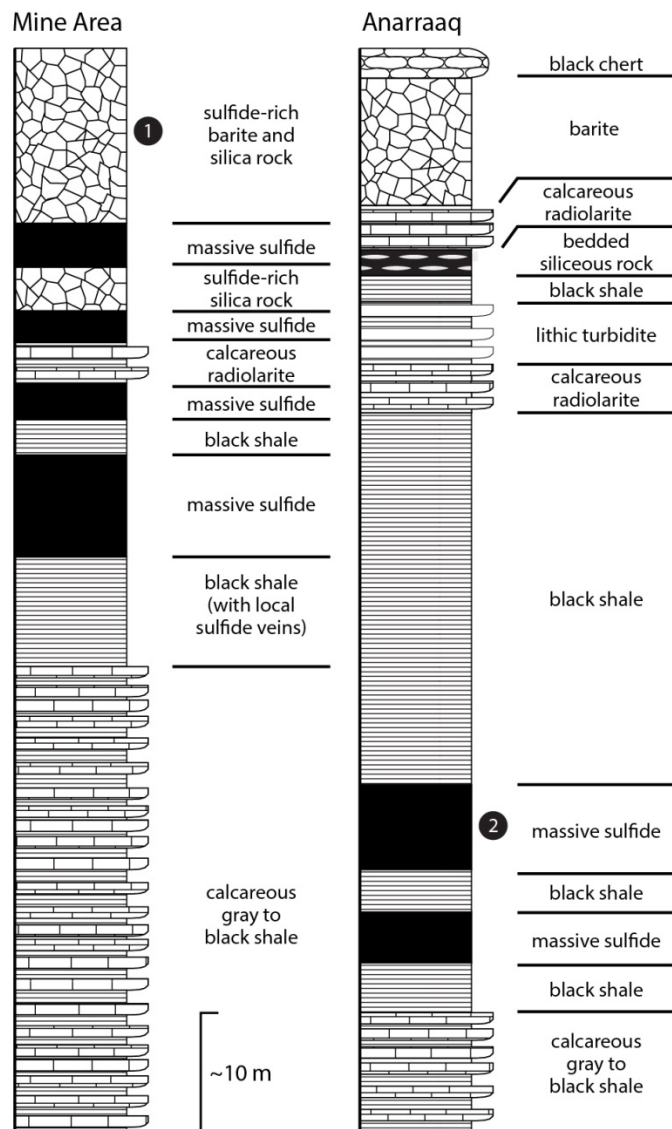


Figure DR2. Generalized stratigraphic column of the Kuna Fm. in the Mine Area deposits and Anarraaq deposit (after Fig. 3 in Slack et al., 2004). Solid black circle 1 indicates the part of the stratigraphic column represented by samples in Figs. 2A, 2B, 2C, DR3, and DR4A. Solid black circle 2 indicates samples in Figs. 2D, DR4B, and DR4C.

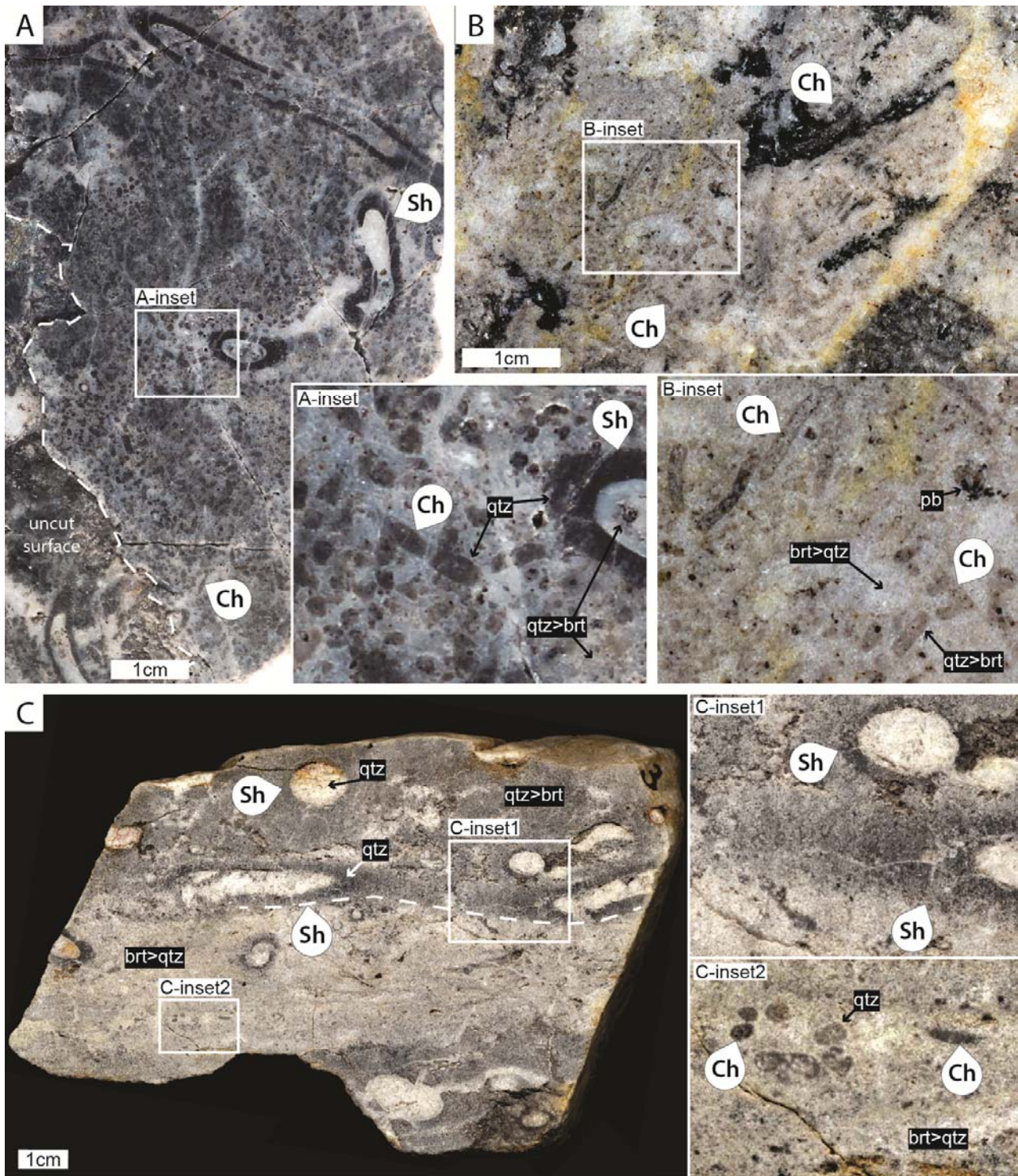


Figure DR3. Additional burrowed samples from the Qanaiyaq deposit. All samples are polished slabs of outcrop samples. **A)** Bedding-parallel sample with abundant *Schaubcylindrichnus* (Sh) and *Chondrites* (Ch). *Schaubcylindrichnus* linings are composed of dark grey quartz (qtz); infill and matrix are composed of light grey quartz > barite (qtz>brt). Note that *Schaubcylindrichnus* traces commonly crosscut bedding plane. *Chondrites* are also composed of dark grey quartz (qtz) and a branching example is highlighted in the inset. **B)** Bedding-parallel sample contains locally abundant *Chondrites* composed of quartz > barite (qtz>brt) in a matrix of barite > quartz (brt>qtz). Matrix also contains patches of pyrobitumen (pb). Inset is the same image as in Fig. 3B. Note branching *Chondrites* highlighted at right of inset. **C)** Bedding-perpendicular sample (way up unknown) shows one

Schaubcylindrichnus burrow following bedding plane for nearly the entire length of the sample. The diameter of *Schaubcylindrichnus* burrows are especially large in this sample, ranging up to approximately 1 cm. *Schaubcylindrichnus* linings and *Chondrites* burrows are composed of dark grey quartz. *Schaubcylindrichnus* infill is composed of barite and the matrix contains variable amounts of light grey quartz and barite.

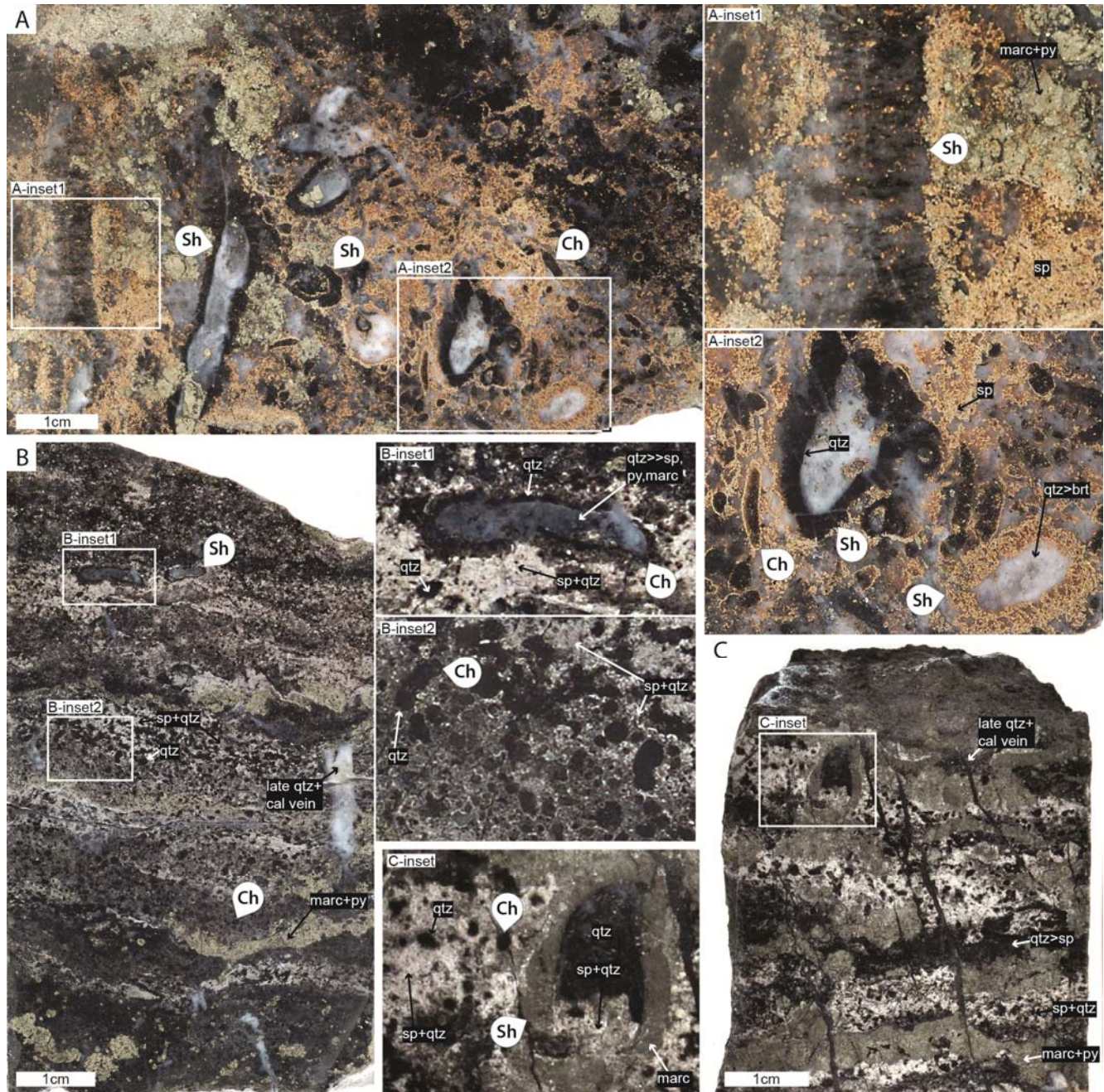
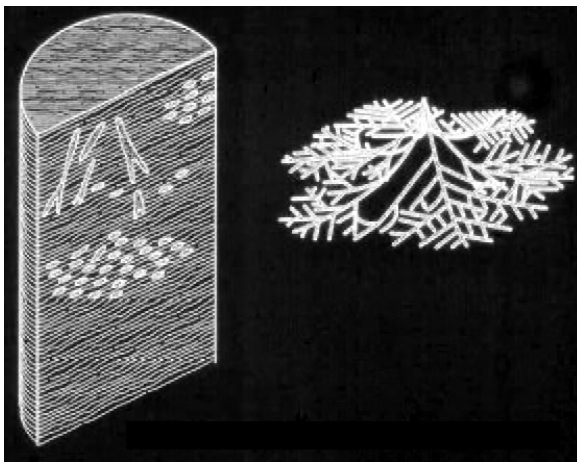
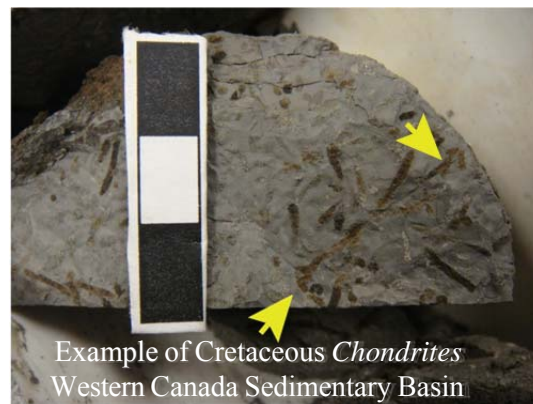


Figure DR4. Additional burrowed samples from Red Dog ore zones. All samples are polished slabs of outcrop specimens (A) and drill core (B-C) and are shown in depositional orientation unless otherwise noted. A) Sample of unknown orientation from the Aqqaluk deposit contains abundant *Schaubcylindrichnus* (Sh) and *Chondrites* (Ch) burrows. The upper inset shows the very edge of a *Schaubcylindrichnus* burrow intersecting sample surface in a matrix of marcasite (marc), pyrite (py), and sphalerite (sp). We tentatively interpret the lining texture to be meniscate infill, which would provide further evidence of the biogenicity of these traces. Inset A2 is the same image as Fig. 3C.

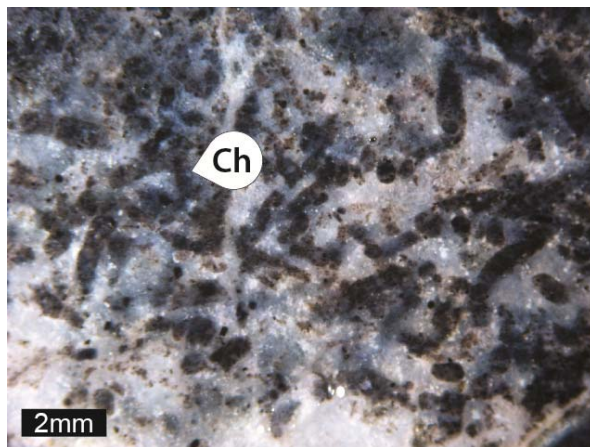
Schaubcylindrichnus linings are composed of dark grey quartz (qtz) or sphalerite (sp) and infilled with light grey quartz > barite (qtz>brt). *Chondrites* are composed of dark grey quartz (qtz). Note that thin rims of sphalerite occur locally on both *Schaubcylindrichnus* (see highlighted burrow in middle of main image) and *Chondrites* (see highlighted burrow in inset A2). We interpret these rims to be reactive boundaries between trace and matrix, not linings. **B)** Bedding-perpendicular sample from Anarraaq ore zone. Possible *Schaubcylindrichnus* and abundant *Chondrites* are highlighted in inset images. *Schaubcylindrichnus* linings and *Chondrites* are composed of dark grey quartz (qtz) in a matrix of intergrown sphalerite and quartz (sp+qtz). *Schaubcylindrichnus* is infilled with light grey quartz (qtz). **C)** Bedding-perpendicular sample from Anarraaq ore zone. The *Schaubcylindrichnus* lining is composed of marcasite (marc) and infilled with quartz and a zone of intergrown sphalerite and quartz, which we tentatively interpret to be geopetal. Possible *Chondrites* are composed of quartz. Matrix is composed of intercrystalline sphalerite and quartz or marcasite.



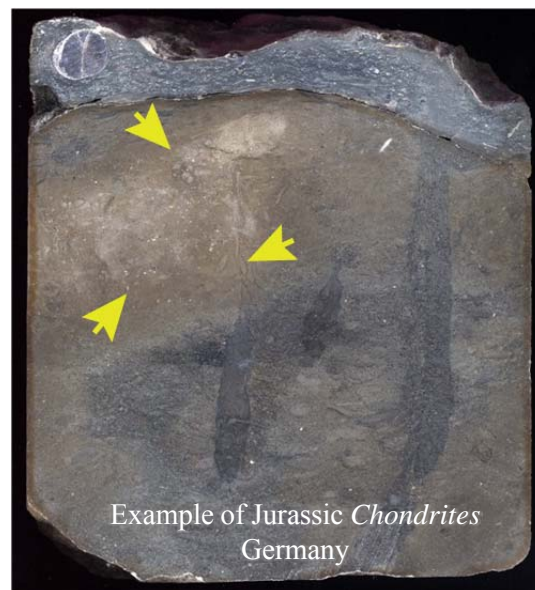
Schematic interpretation of *Chondrites*.



Example of Cretaceous *Chondrites*
Western Canada Sedimentary Basin



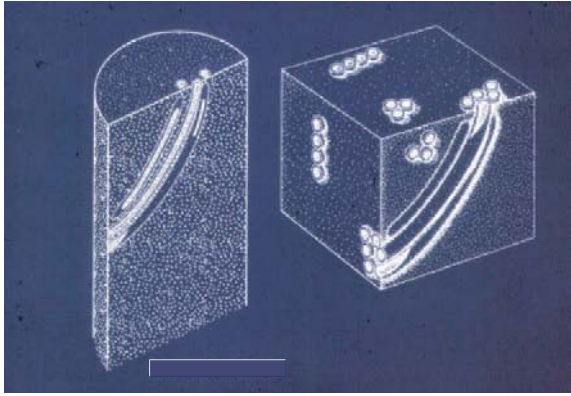
Example of *Chondrites* (Ch) this study.



Example of Jurassic *Chondrites*
Germany

Figure DR5. Schematic and several examples of *Chondrites* in non-hydrothermally altered samples compared with Red Dog sample. **Description:** *Chondrites* is a complex root-like burrow system of regularly branching feeding tunnels of uniform diameter which never anastomose, interpenetrate, nor cut across one another (photo taxis). However, individual *Chondrites* can crosscut each other due to time averaging. Branching typically is in the form of side branches (up to five or six orders) angling off a higher order or main tunnel at 30 degrees to 40 degrees rather than bifurcating at Y-shaped junctions. In core, *Chondrites* commonly appears as an array of tiny elliptical dots where the vertical slice through the

core truncates the numerous branching tunnels. In some instances, longitudinal sections through individual tunnels and broken portions of branches are exposed. **Interpretation:** It has been suggested that *Chondrites* represents tunnels produced by a deposit-feeding sipunculid, which worked from a fixed centre on the substrate surface and created tunnels by extending its proboscis. However, some forms of *Chondrites* penetrate so deeply into the substrate that they could have been only produced by a vermiform animal dwelling within the structure, moving bodily through the sediment in the manner of the modern polychaete *Heteromastus*.



Schematic interpretation of *Schaubcylindrichnus*.



Modern agglutinated polychaete tube.



Left and above are Mesozoic examples from the Western Canadian Sedimentary Basin.



Example of *Schaubcylindrichnus* this study.

Figure DR6. Schematic, modern trace former, and several examples of *Schaubcylindrichnus* in non-hydrothermally altered samples compared with Red Dog sample. **Description:** Plural curving tubes, gently arcuate with upper ends of the tubes being vertical, whereas lower ends are approximately horizontal. Isolated sheaves or bundles of closely juxtaposed, congruent, well lined, equisize tubes that do not taper, branch, or interconnect. Number of tubes making up an individual sheaf is variable but as many as 20 per sheaf have been described. Both interior and exterior surfaces of the tubes are smooth and unornamented. Recently amended to include solitary curving tubes (formerly *Terebellina*; Miller, 1995). **Interpretation:** *Schaubcylindrichnus* is interpreted as the communal domicile of either suspension feeders or head-down tubicolous deposit feeders such as the modern maldanid polychaete *Clymenella torquata*.

Sample Name	Deposit	Type	Figure	Location
809-728.2m (2389.2ft)	Anarraaq	Diamond Drill Core	Fig. 3D, Fig. DR3B	*
923-672m (2204.6ft)	Anarraaq	Diamond Drill Core	Fig. DR3C	*
MB-01	Aqqaluk	Hand Specimen	Fig. 3C, Fig. DR4A	†
QB-002	Qanaiyaq	Hand Specimen	Fig. 3B, Fig. DR3B	UTM zone 3W 590344E, 7550422N§
QB-003	Qanaiyaq	Hand Specimen	Fig. 3A, Fig. DR3A	UTM zone 3W 590344E, 7550422N§
QB-004	Qanaiyaq	Hand Specimen	Fig. DR3C	UTM zone 3W 590344E, 7550422N§

Table DR1. Sample location details. *The location of drill holes 809 and 923 can be found on page 1578 in Kelley et al. (2004). †Sample MB-01 was taken from a set of samples belonging to the exploration geology team and is most likely from the Aqqaluk deposit, but could also be from the Main deposit. As the Main and Aqaluk deposits have been mined extensively, this is one of the few existing hand specimens accessible from those deposits. §QB samples were collected within ~100m of this GPS point.

REFERENCES

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