Distal evidence (?) of the Late Triassic (Norian) Manicouagan impact, northeastern Quebec: New data from the Fundy Group (Canadian Maritimes)

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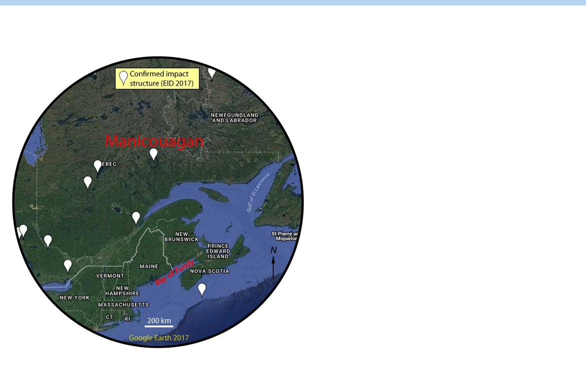

Abstract

Preliminary petrographic analysis (optical and scanning electron microscopy) was conducted on samples from selected horizons in the nonmarine Upper Triassic Blomidon and Middle (?) Triassic Quaco formations (Fundy Group) from three Bay of Fundy coastal localities: Five Islands/Red Head and Houston Beach/Delhaven, Nova Scotia; and St. Martins, New Brunswick. Results to date from the Blomidon Formation reveal the presence of multiple sand-grade intragranular fracture sets potentially indicative of high magnitude Late Triassic (Norian) paleoseismicity consistent with the Manicouagan (distal) impact causal model proposed previously. Samples of particular interest include fluvial and eolian sandstones collected from the formation's White Water Member 'synsedimentary' deformation zones ('DH1' and 'DH2') exposed on the Blomidon Peninsula (Nova Scotia) previously attributed, in an alternative model, to basin-wide, meter-scale subsurface evaporite dissolution and stratal collapse effects. These chaotically deformed units contain (rare) transported quartz grains displaying open microfracture (radial and spallation) styles considered to be diagnostic genetically of dynamic concussion (i.e., rapid seismic shock) origin. However, precise controls on, and the timing of, this microdeformation still remain uncertain due to the paucity of unequivocal associated distal ejecta material (e.g., shocked quartz, microspherules, PGE anomalies and/or heavy minerals) from the Manicouagan impact. Similarly fractured, dominantly quartzite cobbles comprise the Middle (?) Triassic fluvial conglomeratic Quaco Formation at the third locality, St. Martins, New Brunswick on the western Fundy coastline (Stonehammer Geopark). These rudites have also been interpreted tentatively as in situ evidence of a major regional (post-?Carnian) paleoseismic event, possibly synchronous with that considered responsible for the lower Blomidon Formation synsedimentary deformation observed in the Minas Subbasin approximately 100 km to the east.

Geologic Setting

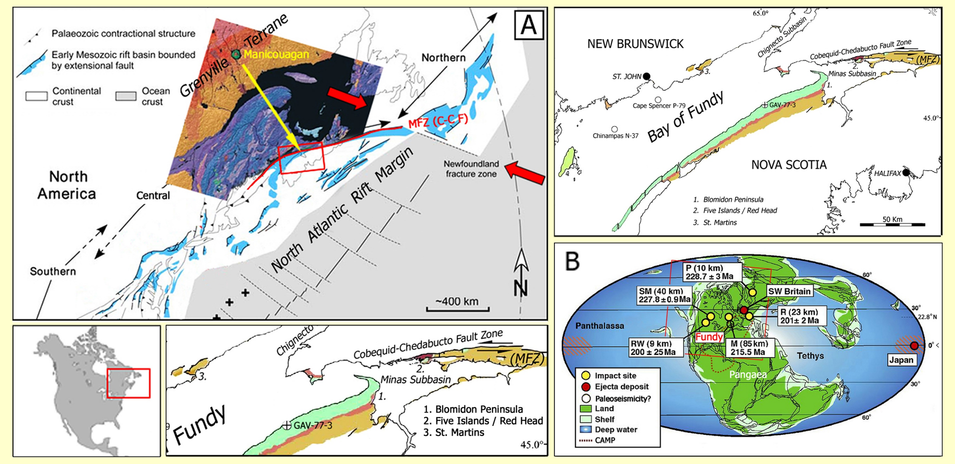

Figure 1: **A.** Regional geological setting showing the present-day location of the Manicouagan impact structure, major structural elements, and the coastal outcrops in Figs 3, 4 and 5. B. Late Triassic global paleogeographic map highlighting extant Manicouagan distal ejecta occurrences in Britain and Japan. (Modified from Clutson *et al.* 2017 after Onoue et al. 2012)

Background

The Late Triassic (Norian, ca. 215 Ma) Manicouagan bolide impact structure, located within the Grenville geologic province of northeastern Quebec, Canada comprises the third largest confirmed impact during the Phanerozoic era (after Chicxulub and Popagai). Intra-continental target rocks comprised a mixture of variably thick Palaeozoic carbonate/clastic sedimentary cover on Proterozoic crystalline basement. The proximal expression of this relatively well-preserved ~85 km diameter crater has been studied in various detail, most recently as part of the Manicouagan Impact Research Project (MIRP) based at the University of New Brunswick. Published records of distal ejecta and associated geologic information beyond crater signature is considerably less extensive (Clutson et al. 2017). Key exceptions include (tentative) Norian-aged spherulite occurrences in southwest Britain (fluvial) and central Japan (pelagic marine), as well as interpreted (fluvial-playa-lacustrine) impactites and 'seismites' in eastern Canada <750 km southeast of the crater site. This wide distribution suggests other fall-out signatures are likely to be preserved elsewhere, either as a discrete 'Chicxulub-style' layer and/or disseminated via re-working throughout a broader, possibly more complex stratigraphic interval.

Stratigraphy and Timing

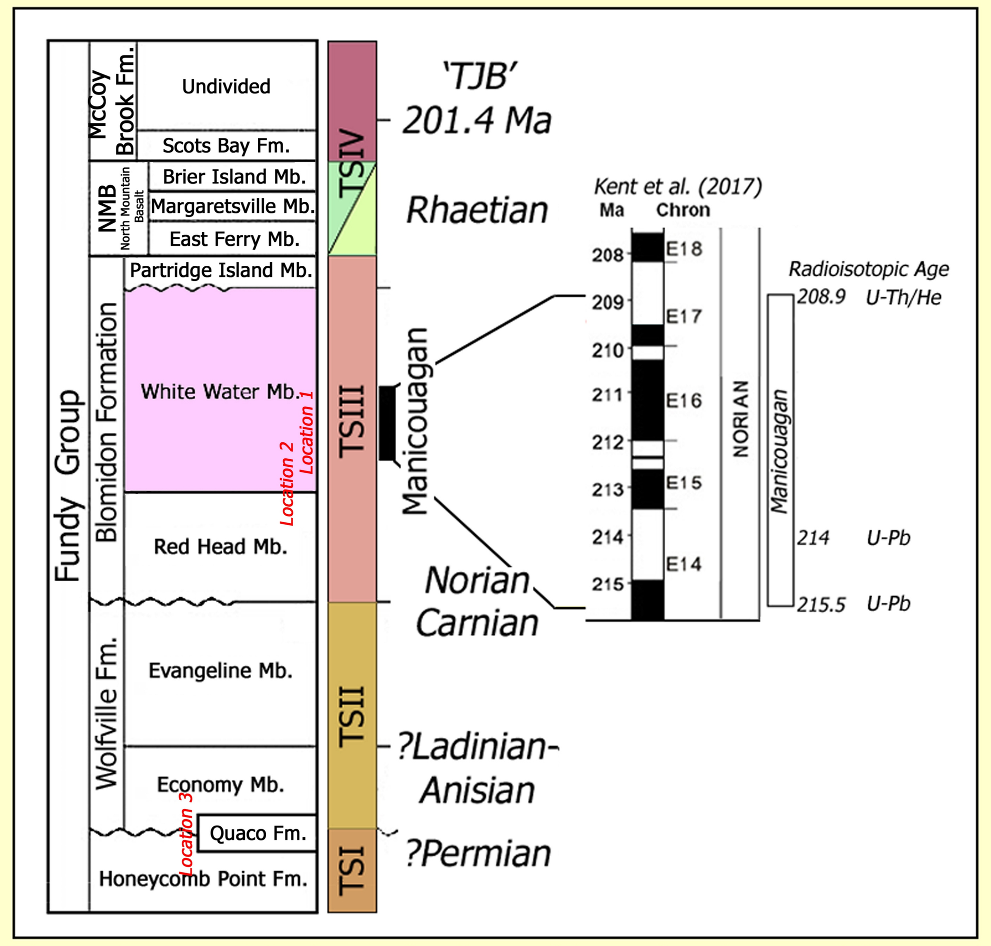

Figure 2: Late Triassic Fundy Group lithostratigraphy containing the sedimentary deformation sections referenced above, plus the Manicouagan radioisotopic age range based on recent Newark Basin magnetostratigraphy.

Field and Petrographic Observations

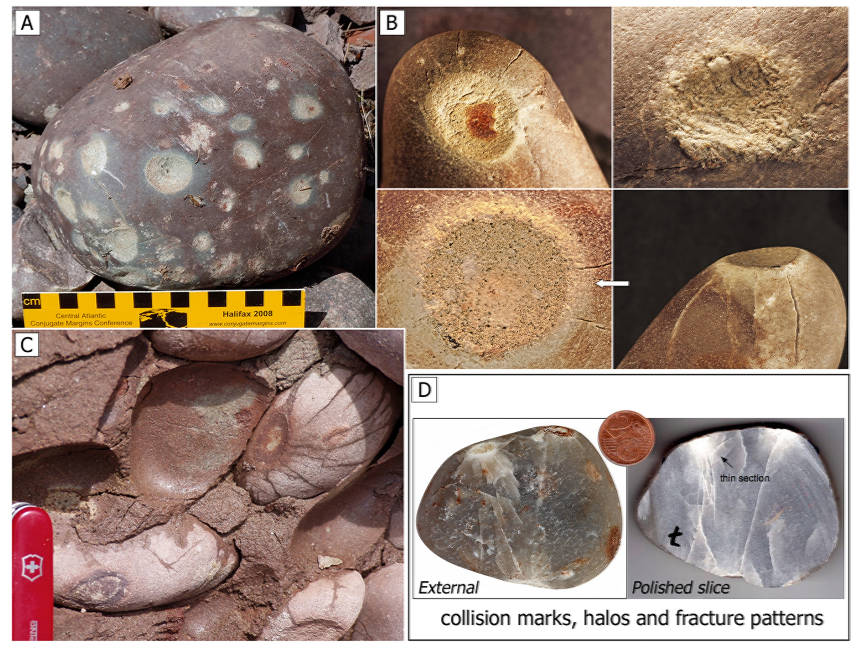

Figure 6: Quaco Formation cobble deformation styles: **A.** Circular to elliptical surface markings and indentations. **B.** Halo and radial fracture details. **C.** Outcrop detail. **D.** External vs internal collision marks, contact halo and associated fracture expressions (Ernstson 2016 pers. comm.)

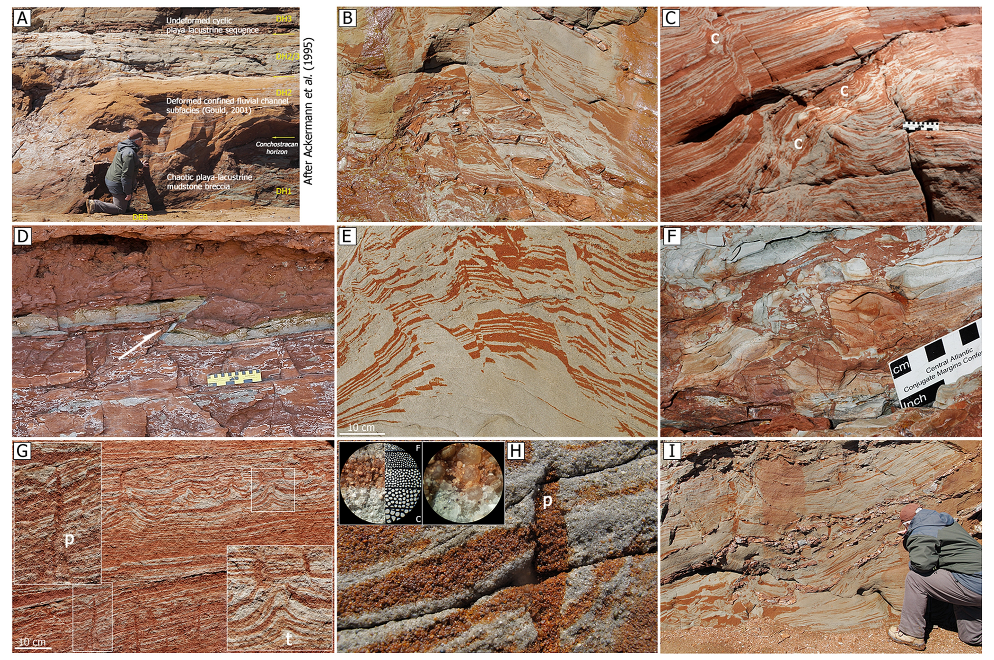

Figure 8: Examples of macroscale sedimentary deformation features (SSDS *sensu lato*) observed within the Blomidon Formation (White Water Member) at Houston Beach. Deformation unit terminology (DH=Delhaven) after Ackermann et al. (1995).

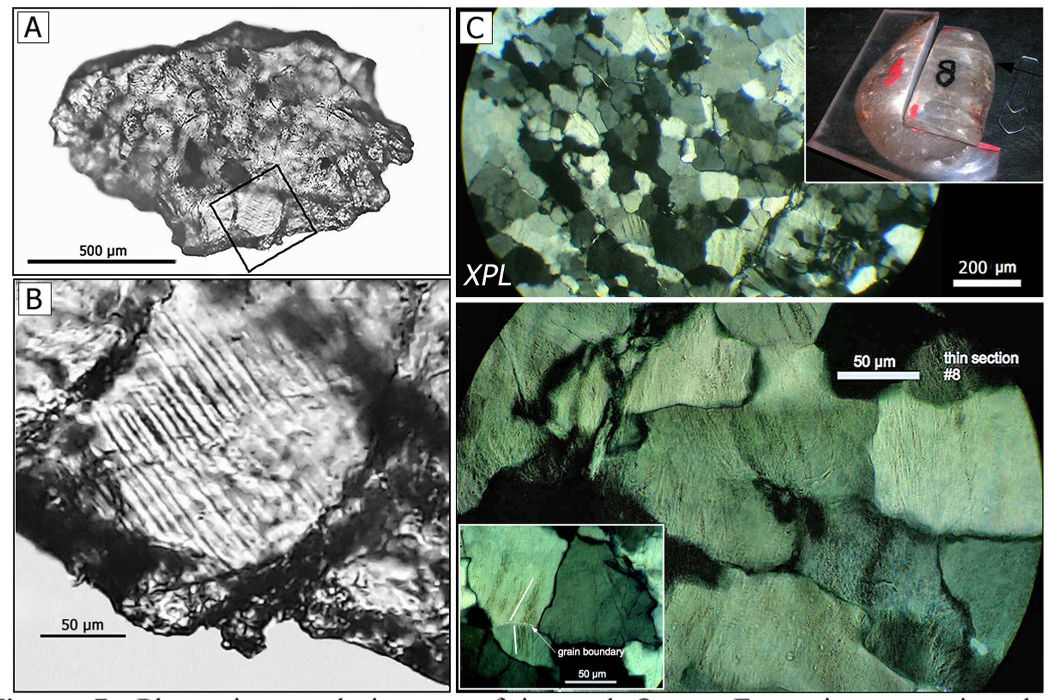

Figure 7: Photomicrograph images of internal Quaco Formation quartzite clast microdeformation features. **A.** Local parallel planar sets and **B.** Single quartz grain lamellae both under transmitted light. **C.** Petrographic thin section (XPL) views of multiple quartz planar lamellae sets (PF and/or ?PDFs; Ernstson 2016, pers. comm.).

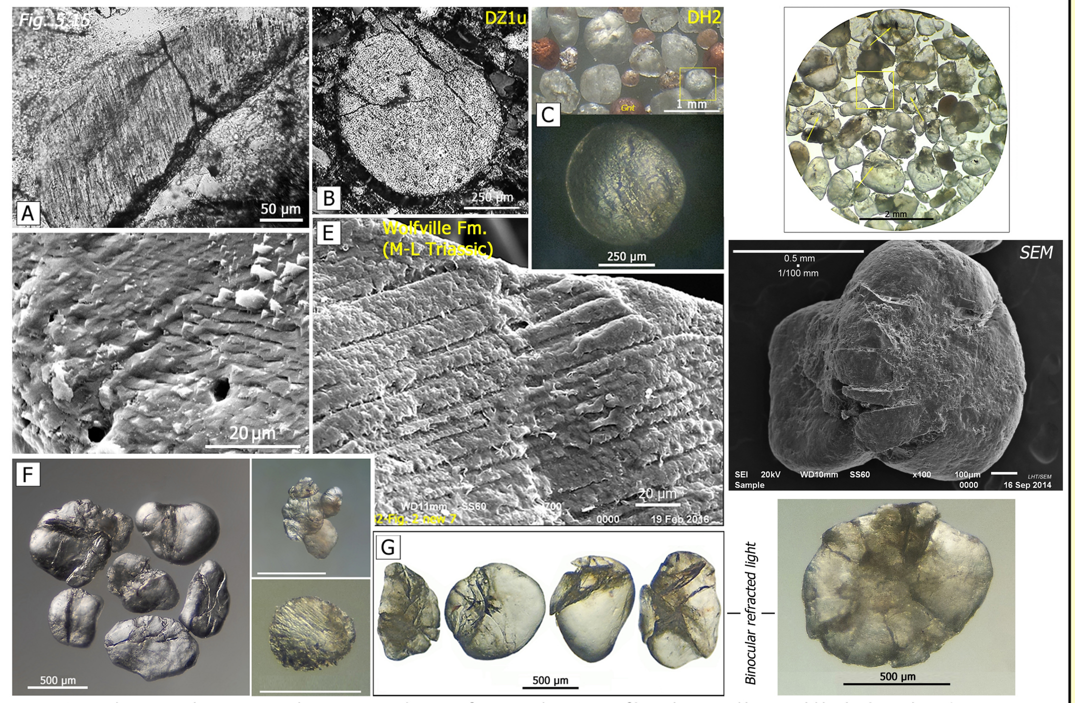

Figure 9: Photomicrograph examples of Fundy Gp fluvio-eolian siliciclastic (quartz and plagioclase feldspar) grain microdeformation styles from the sampled Five Islands and Houston Beach Lower Blomidon Fm sections. Upper Wolfville Fm (Evangeline Mbr) HF etched SEM granular planar features from the southern Minas Subbasin (LHT 2016). Figure modified from Clutson et al. (2017, Fig. 5.12).

Conclusions

Evidence pertaining to the Late Triassic (Norian) Manicouagan bolide impact significantly beyond crater signature appears to be severely limited, while that which has been found to date remains controversial notably concerning reliable age-dating and possible alternative origins. However, important clues present within several, easily accessible Bay of Fundy coastal localities (in addition to SW Britain and Japan) provide insights as to where pertinent data might be found stratigraphically, and possibly expressed discretely elsewhere within the geologic record (sensu Schedl 2015). The currently evolving Manicouagan 'global' scenario - if supportable by additional and correlatable diagnostic impact datasets - hopefully will enable the development of a working multi-regional (initially North America, West-Central Europe and Eastern Asia) geologic model offering the capacity to be expanded globally.

Future Work

Ongoing international technical studies investigating the Manicouagan distal impact story, including associated paleoenvironmental effects, support a growing need to:

- Clarify why researchers have consistently been unable to identify remote impact evidence of this major intra-Norian catastrophic event - is it simply an ejecta preservation (and/or recognition) issue?
- Determine - through selectively focused research - the types of diagnostic criteria (physical, geochemical / isotopic and biological) that have remained preserved within the distal stratigraphic record and the factors controlling these occurrences.
- Facilitate the applicability of Manicouagan project methods and results to investigating other Late Triassic impact scenarios e.g. Saint Martin (CD) and Rochechouart (FR), including any direct or indirect contributions to multiple terrestrial and marine biotic turnovers, potentially culminating in the end-Triassic mass extinction.

Acknowledgements

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St. Martins, NB

Figure 3: Quaco Fm. Fig. 7C sample location (DEB 2014).

Five Islands, NS

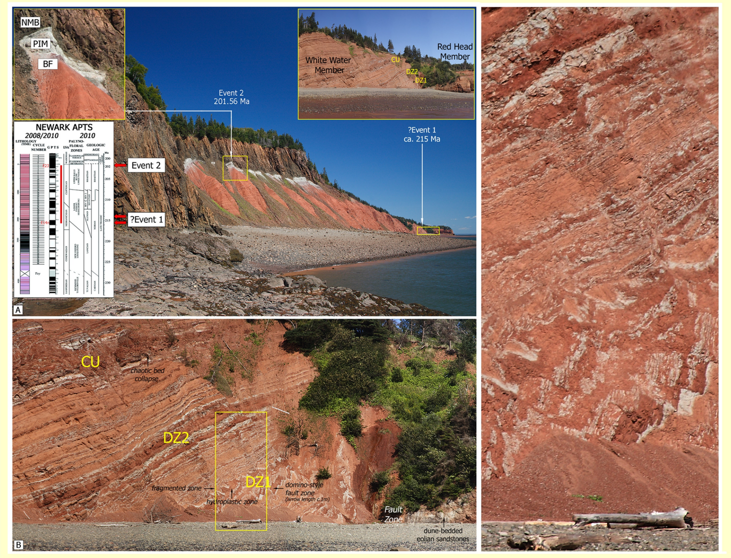

Figure 4: Blomidon Fm. units sampled by Tanner (2006).

Houston Beach, NS

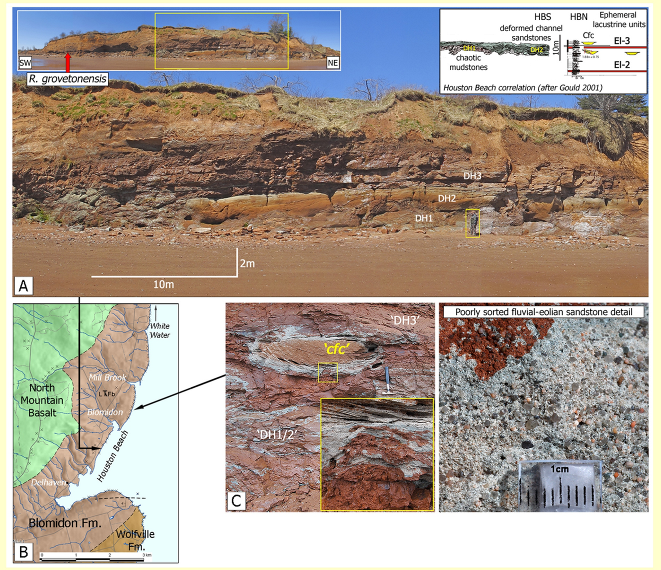

Figure 5: Delhaven coastal section *sensu* Ackermann *et al.* (1995).

Types of Interpreted Distal Evidence

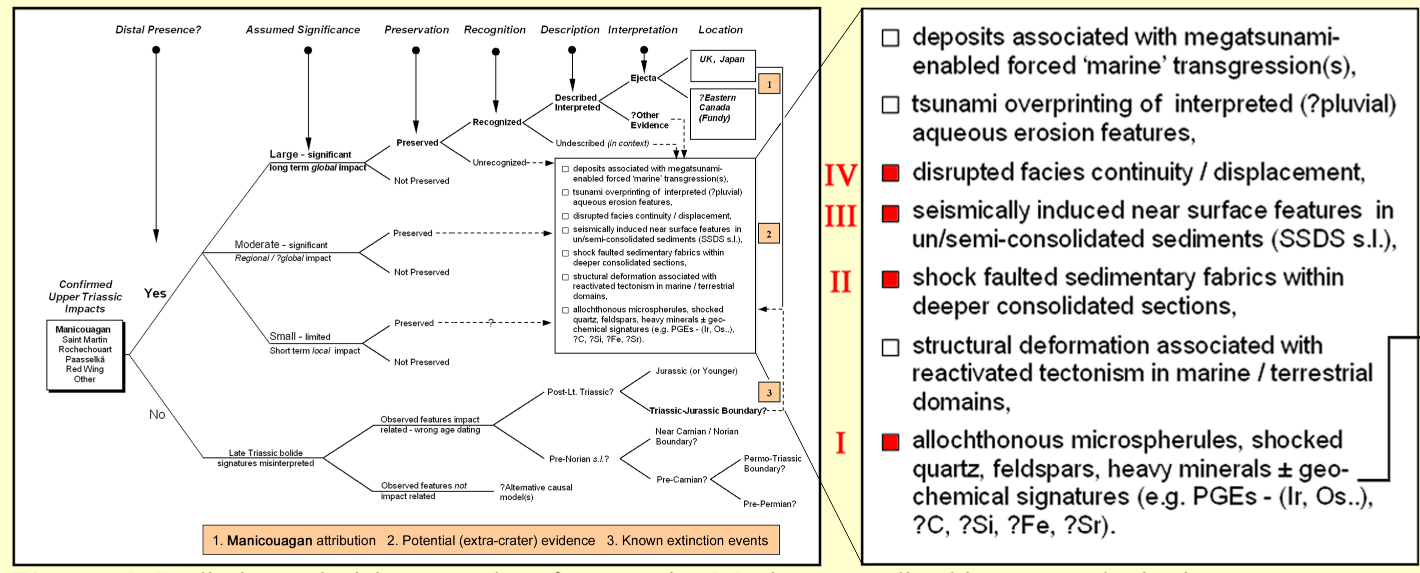

Figure 10: Preliminary decision-tree chart for assessing Manicouagan distal impact geologic signatures.

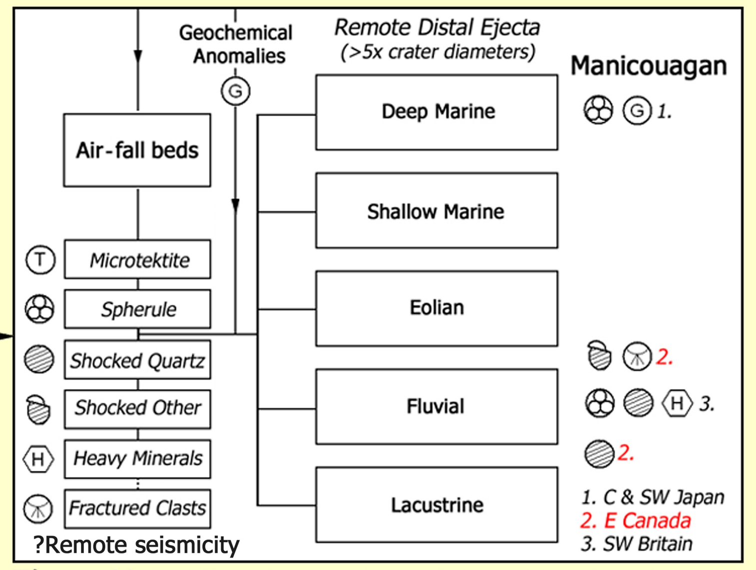

Figure 11: Published examples and depositional setting.