SUDBURY IMPACT EJECTA FEATURES IN BASE SURGE DEBRISITES NORTH OF LAKE SUPERIOR, ONTARIO, CANADA. W. D. Addison, G. R. Brumpton, P. W. Fralick, and S. A. Kissin, Department of Geology, Lakehead University, 955 Oliver Road, Thunder Bay, P7B 5E1, Canada. E-mail: baddison@tbaytel.net.

Introduction: Eight new sub-aerially exposed debrisites containing ejecta from the 1850 Ma [1] Sudbury impact event have been found in and near the City of Thunder Bay, north of Lake Superior, Ontario (Fig. 1). These exposures are interpreted as base surge deposits whose features differ significantly from previously described ejecta units in drill cores. Ejecta features in the debrisites include PDFs and planar fractures in quartz grains, vesicular devitrified glass clasts, unshocked angular and sub-rounded quartz and feldspar grains, accretionary lapilli and possible microtektites.

The Debrisites: Two sites show in situ fractured Gunflint chert-carbonate at the base of the debrisite indicative of earthquake activity prior to debrisite deposition. All sites show clasts of shattered Gunflint chert-carbonate in the debrisite ranging from sub-millimeter shards to blocks over a metre in size. The debrisite also contains large quantities of microcrystalline carbonate that we interpret as a pre-impact, sub-aerial lagoon floor sediment. Thus, powerful activity stripped the sediment down to bedrock, incorporating it and a shallow layer of earthquake-shattered Upper Gunflint chert-carbonate into the debrisite, heavily diluting the ejecta.

The debrisites range from ~ 0.3 m to ~3.5-4 m in thickness and lie on chert-carbonates, which are part of a marine regressive assemblage at the top of the Gunflint Formation. Only one site exposes the transition from debrisite to overlying Rove Formation shale. Glacial erosion has truncated the vertical extent of the other seven sites. Most of the debrisites rest on in situ microbialites or stromatolites, suggesting, at the least, a moist depositional environment if not a peritidal environment.

Base Surge: A variety of features suggest the debrisite was deposited sub-aerially:

1. The ocean regression assemblage indicates a trend toward sub-aerial exposure.
2. Most importantly, four debrisite sites show an iron-rich alteration profile (a possible paleosol) 0.5-1.5 m below the debrisite.
3. Devitrified vesicular glass is very common at the base of the debrisite, some of it so vesicular that its density may have approached that of water. If it was deposited in water, it should be stratified in the debrisite with the least vesicular clasts near the base of the debrisite with the more vesicular clasts higher in the stratigraphic column. This is not the case.
4. Some vesicular clasts have ovoid vesicles with their long axes aligned parallel to each other, suggesting that the clasts were deposited while still warm enough to be deformed by the weight of overlying debris. Had water been present, it would have quickly quenched the still warm glass, preventing its deformation.

In the absence of water, base surges and/or air fall are the remaining options for deposition of the debrisite. An air fall deposit should show obvious upward fining, and it should not contain large Gunflint clasts. The debrisite does not fine upwards, and it does contain many Gunflint clasts, some over a metre in size. Thus, we conclude that the debrisites are base surge deposits laid down on a sub-aerial Gunflint surface.

Post-depositional History: Previous geochronology work with drill core material has shown that ~ 15 My passed from when the 1850 Ma debrisite was deposited until dated zircons just 6 m higher in Rove Formation tuff were deposited [2]. Such a minor amount of sediment for ~ 15 my strongly suggests a depositional hiatus and a period of sub-aerial exposure before the ocean again transgressed the area depositing the organic-rich mud and volcanic ash layers of the Rove Formation. Several features within the debrisite support this idea.

At the only site where the top of the debrisite is present, a period of sub-aerial exposure appears to have led to weathering, leaching, erosion and removal of an unknown quantity of debrisite. These processes likely moved or removed the late stage fine air fall material that would have settled onto the base surge debrisite making it unlikely that spherules and a fireball layer will be found near Thunder Bay. The leaching led to the formation of an iron-rich (primarily pyrite) alteration profile similar to that seen below the debrisite at four locations. The physical and chemical features of blocky calcite cement in the debrisite indicate its formation in the freshwater phreatic zone [3].

Post-depositional anastomosing chert and agate ridges stand out from the more easily weathered debrisite at some sites. Comparable microscopic anastomosing chert is seen in thin sections. We interpret the anastomosing chert as a precipitate from sub-aerial leachate produced higher in the debrisite.

In some cases silica or silicates have replaced ejecta features; however, carbonate replacement is far more common. Replacement complicates the interpretation of ejecta features by destroying detail within the features or by destroying the entire feature. For example, it is impossible to determine if carbonate replaced features, which show the size and shape of microtektites, including syneresis cracks, are in fact microtektites because the key textural and color features have been destroyed. Recrystallization of the replacement carbonate has further compounded the problem.

The debrisite is overlain by a carbonate-rich ocean transgressive assemblage ~ 0.7 m thick which shows millimeter-sized mudstone rip-ups, centimeter-sized carbonate rip-ups and cross bedding features, further supporting the period of sub-aerial exposure. There is an abrupt transition from the transgressive assemblage to the Rove Formation shale which, in turn, has been intruded by a Logan diabase sill. Heat from the sill may explain why carbonate replacement and recrystallization is so pervasive and why it has been so destructive of ejecta features at this site compared to other sites.

Conclusion: A variety of features support the hypothesis that the study area was sub-aerial before, during and after base surges deposited the debrisites, containing a multifaceted mixture of ejecta and non-ejecta features, which allow interpretation of a rich, complex history. These debrisites may well be useful Earthly analogues for those studying Martian impacts, especially in terms of accretionary lapilli [4] and, perhaps, chemical alteration profiles.

References: [1] Krogh T. E. et al. 1984. pp. 431-446 *in* The Geology and Ore Deposits of the Sudbury Structure. Ontario Geol. Survey., Spec. Vol. 1. [2] Addison W. D. et al. 2005. Geology 33: 193-196. [3] Fralick P. W. and Burton J. Goldschmidt 2008: abstract 1342. [4] Knauth L. P. et al. 2005. Nature 438: 1123-1128.

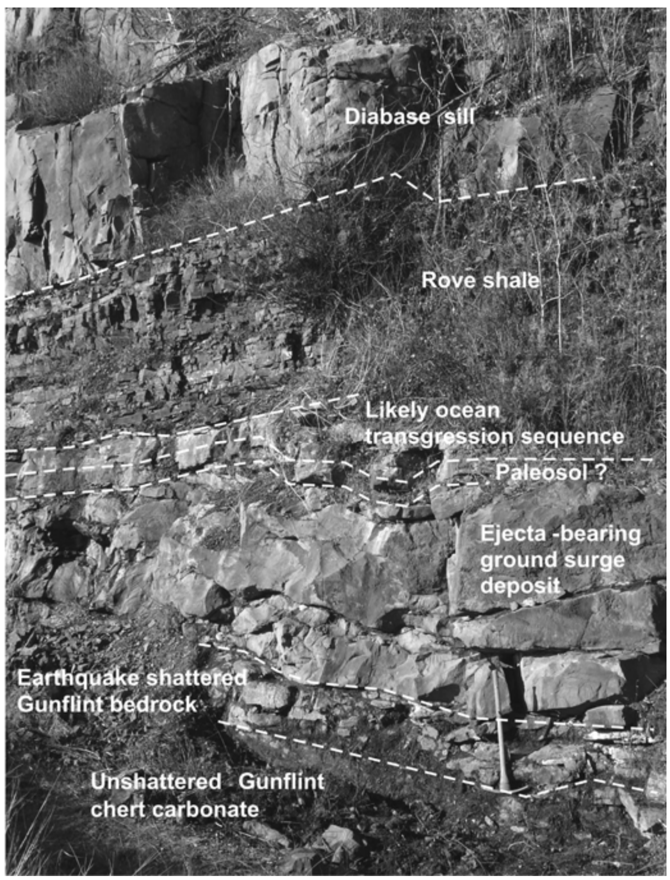

Figure 1. The Highway 11-17, Terry Fox Lookout site is the only one of the eight sites showing a complete stratigraphic section. This photo extends from unfractured Upper Gunflint Formation chert-carbonates → earthquake shattered, slickensided Gunflint chert-carbonate clasts (~ 0.5 m) → ejecta-bearing base surge debrisites (~ 2.2 m) → an iron-rich alteration profile (possible paleosol, 0.3-0.5 m) → marine transgressive assemblage (~ 0.7 m) → Rove Formation shale. An iron-rich alteration profile, ~ 1.5 m below the debrisite in the Gunflint, lies to the right out of the photo. The study area was sub-aerially exposed between the two alteration profiles, a period ≥ 15 My.