Dustin TRAIL
Lewis & Clark Fund for Exploration and Field Research in Astrobiology

Project Report

A field and geochemical investigation of the oldest known rocks on Earth: the ca. 4.03 billion year old Acasta Gneiss complex, Canada.

Dustin Trail

Department of Earth & Environmental Sciences and New York Center for Astrobiology
Rensselaer Polytechnic Institute, Troy, NY 12180, USA

The purpose of this report is to highlight some of the preliminary findings from field work conducted during the summer of 2009 at the Acasta Gneiss Complex, in Northern Canada. These rocks are significant because they are the oldest known rocks —over 4 billion years old (Ga)—and offer a unique opportunity to gain insight into the formative stages of Earth history. The location of collected hand samples will be highlighted below, along with a brief description of the significance of some key rock outcrops. This will include what is already known from previous workers, and a number of important questions that still need to be answered.

Fig. 1 shows: **(a)** the general location of the Acasta Gneiss Complex and **(b)** a high resolution view with GPS coordinates imported into Google Earth ® that provides an overview of the sampling localities.

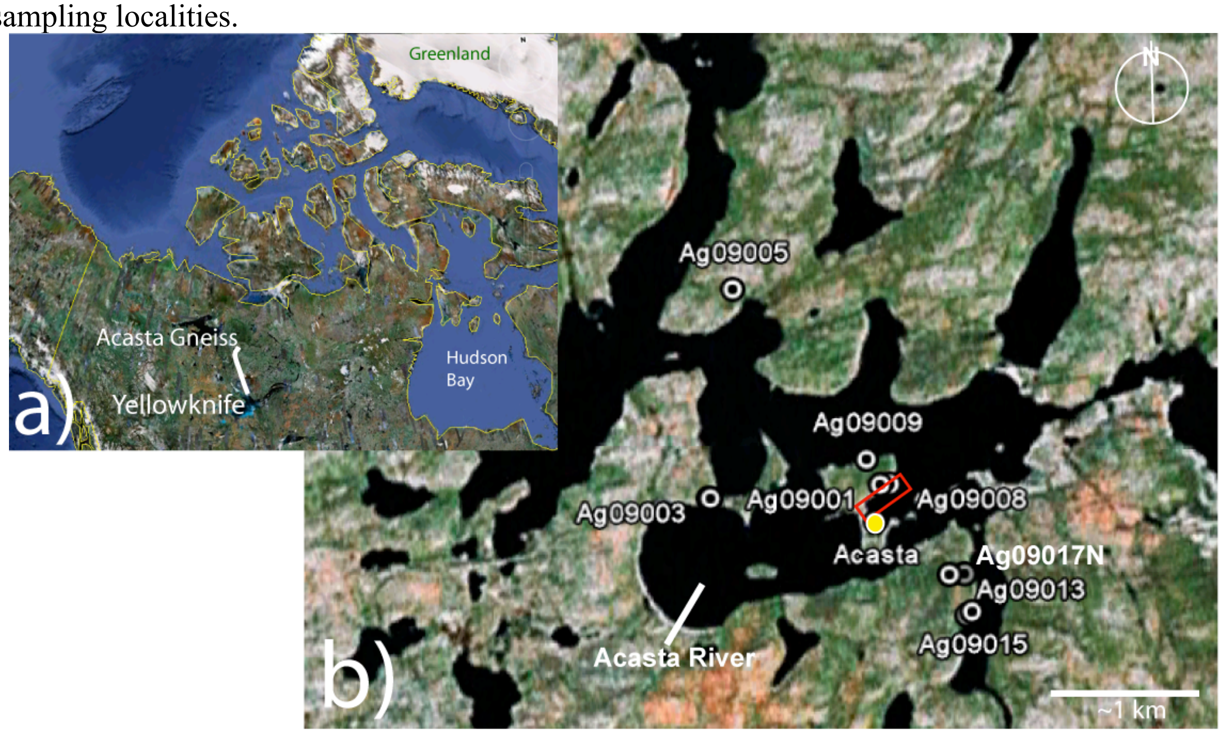

Fig 1. Images constructed in Google Earth ® highlighting: **(a)** the float plane trip up to the Acasta Gneiss Complex and **(b)** the aerial photo of the main sampling area undertaken during field work with some annotated sample localities (others removed from clarity). The island containing the red box was the location of our camp, and is also believed to be the location of the first 4.0 Ga rocks discovered in the region. The red box also indicates the location

of the image in **Fig. 2**. The yellow dot indicates the location of camp, and the spot from which the image in **Fig. 2** was taken.

The red box in **Fig. 1** highlights a key area of the Acasta Gneiss which is shown in **Fig. 2**. The image in **Fig. 2** was taken approximately from the yellow dot, (N65°09.978', W115°33.681') facing approximately north.

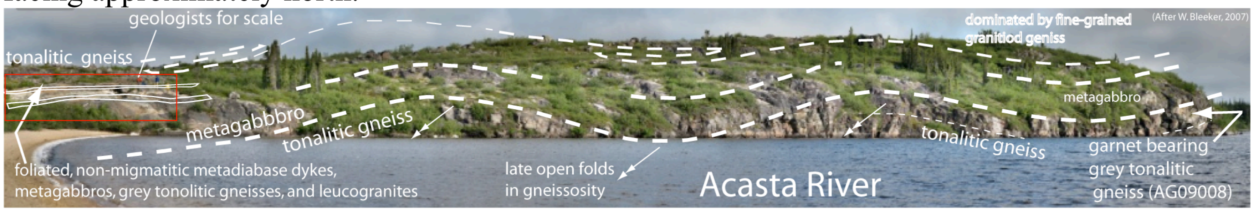

Fig 2. Sketch overview of the Acasta gneisses on the island where camp was located in the Acasta River. This outcrop is believed to be close to the sampling location where ca. 4.0 billion year old rocks were first discovered (Bowring et al., 1989; Bowring and Williams, 1999). This photo was taken looking north toward the northern peninsula of the island (see yellow dot in Fig 1). The rocks are composed of interleaved gabbroic, tonalitic and granitic gneisses, and the folds are Paleoproterozoic in age. The high resolution image (280 megapixels) can be found at: http://gigapan.org/viewGigapan.php?auth=7804e088738b63898e89b64622247149. In addition, the red box at the left of the image highlights a particularly well exposed region of these rocks. The high resolution Gigapan ® image of this figure (790 megapixels) can be found at: http://share.gigapan.org/viewGigapan.php?auth=85a8b52a9bff97fab721bf0eaaacaab6 .

AG09003 (GPS: N65°10.058' W115°35.194'): Though precise mapping and GPS coordinates were not available from the earliest reports of these rocks, this sample is probably equivalent to sample number 94-104 in Bowring and Williams (1999). This sample is best characterized as a banded gneiss of tonalitic composition, and is generally typical of many Acasta Gniess rocks. In addition to the older ~4.03 Ga component, there are a number of zircon/overgrowths found in the leucosome resulting from a ~3.6 Ga event. The oldest component broadly resides in the melanosome; because of the complexity of this rock, analyses will proceed by means of a microslabbing approach, which will guide subsequent whole rock chemical analyses. In addition, this sample has a particularly high yield of old concordant (i.e., undisturbed) zircons. Specifically, one zircon grain reported by Bowring and Williams (1999) gave concordant U-Pb ion microprobe ages of 4.05 Ga, along with a number of 4.03 Ga grains. There is also a ~3.95 Ga zircon population in these rocks (W. Bleeker pers. comm.), perhaps indicative of some event subsequent to primary crystallization. It is interesting to note that this age is also observed in Hadean zircons from the Jack Hills (Trail et al., 2007), possibly indicative of some contemporaneous episode between the Jack Hills detrital zircons and the Acasta Gneiss. It is possible that Ti in zircon thermometry may help to elucidate the origin of this event that could be from a widespread metamorphic event. The event may also have been caused by exogenous influences, such as impacts associated with the late heavy bombardment of the inner solar system (Trail et al., 2007); this will have important implications for the habitability of the early Earth (Abramov and Mojzsis, 2009).

AG09008 (GPS: 65°10.118' W115°33.549'): This sample was collected on the island (see the far right of **Fig. 2**) and may be among the most homogenous sequences of ca. 4.0 Ga rocks; these rocks also show evidence of later Archean disturbances. While the whole rock chemistry has not been done, this rock looks very similar to a diorite, though it was originally mapped as a grey tonalite. There are also garnet grains in this rock with had preliminary Sm-Nd dates of 2.9 Ga, possibly caused by partial recrystallization of a much older component. This sample is also intruded by a *ca.* 3.6 Ga granite which is easily identifiable in hand sample because of the K-feldspar. Thus, the K-feldspar should be avoided in the interest of sampling the most ancient chemically "pure" regions of this rock. This sample has a number of advantages over the previous sample described. First, it is less complex, and young components are easy to visibly identify in hand sample. Second, this sample seems to have more homogenous fraction of the old material (W. Bleeker pers. comm.). That said, AG09003 contains some fraction of grains that are older by ~20 Ma than those found in AG09008. These rocks may represent a section of the mid-crust in the Hadean. Nonetheless, oxygen isotope analysis of zircon and the whole rock may provide evidence that some component of this rock formed at the surface of the Hadean Earth.

AG09015 (N65°09.629' W115°32.788') and **AG09016**. These two "samples" were collected within ~25 meters of each other, in order to sample the "outcrop" that contained a ca. ~4.2 Ga xenocrystic zircon reported by the Iizuka et al. (2006). Using the high precision GPS coordinates in Iizuka et al., (2009) and the map of Iizuka et al., (2006), we noted that the "outcrop" in question appears to be boulders, or "float" material in the Acasta River. The rocks are no longer in place, and were probably removed from their original location by the last glaciation. This is significant because it means that there is a strong possibility that there are other localities outside of the Acasta Gneiss Complex that contain ancient crustal relics, suggesting the reservoir of Hadean crust may be more widespread than previously thought. While it will certainly be time intensive, this preliminary field observation suggests large scale reconnaissance sampling may yield rocks even older than those in the Acasta Gneiss Complex.

AG09017N (N65°09'770' W115°32.857') This sample is best described as a metagabbro, and there are preliminary reports that the rock yields a Sm-Nd age isochron of 4.3 Ga. Many of the metagabbros in the Acasta gneiss are devoid of zircons because of low zirconium concentrations present in mafic residuals capable of zircon saturation. Even though these mafic minerals will be less chemically robust than zircon, a comprehensive study of this rock may be important.

I have highlighted a number of the important samples collected during this field trip from the oldest known rocks in the world. A number of geochemical studies including whole rock analysis, U-Pb dating, Ti-thermometry, and $^{18}O/^{16}O$ isotope measurements will follow.

Abramov O. and Mojzsis, S.J. (2009) Microbial habitability of the Hadean Earth during the late heavy bombardment. *Nature* **459**, 419-422.

Bowring, S. A., and Williams I.S. (1999), Priscoan (4.00-4.03Ga) Orthogneisses from northwestern Canada. *Contrib. Mineral. Petrol.* **134**, 3-16.

Bowring S.A., Williams, I.S., and Compston, W. (1989) 3.96 Ga gneisses from the slave province, Northwest Territories, Canada *Geology* **17**, 971-975.

Iizuka T., Horie K., Komiya T., Maruyama S., Hirata T., Hidaka H., Windley B.F., (2006) 4.2 Ga zircon xenocryst in an Acasta gneiss from northwestern Canada: Evidence for early continental crust. *Geology* **34**, 245-248.

Iizuka T, Komiya T, Johnson S.P., Kon K, Maruyama S, Hirata T. (2009) Reworking of Hadean crust in the Acasta gneisses, northwestern Canada: Evidence from in-situ Lu–Hf isotope analysis of zircon. *Chem. Geol.* **259**, 230-239

Trail, D., Mojzsis, S.J., and Harrison, T.M. (2007) Thermal events documented in Hadean zircons by ion microprobe depth profiles. *Geochim. Cosmochim. Acta* **71**, 4044-4065.