Name: Yuem PARK Report rcvd.2.5.19
Grant Program: Lewis and Clark Fund for Exploration and Field Research in Astrobiology
Project Title: Dramatic global change during the era of animal evolution: a new archive of Neoproterozoic Snowball Earth glaciation from the Tambien Group of Ethiopia

PROJECT REPORT

The Cryogenian Period (~717-635 Ma) of the Neoproterozoic Era represents the dramatic termination of ~1.5 billion years of ice-free continents. It is marked by two severe Snowball Earth glacial events during which land ice extended all the way to the equator (the Sturtian and Marinoan Glaciations) separated by a non-glacial interlude of around 9-19 million years. Contrary to the intuitive expectation that such an extreme climate transition would inhibit life, molecular phylogeny and the fossil record suggest that these Snowball Earths are actually associated with the emergence of multicellular animals. Characterizing the environmental context (the initiation, evolution, and termination of the Neoproterozoic Snowball Earths) within which this major biological transition occurred is critical for improving our understanding of the emergence of complex life on Earth and Earth-like planets.

The target of study for this project was the Tambien Group of northern Ethiopia – a mixed carbonate-siliciclastic sedimentary succession deposited in a back-arc basin that is now part of a large amalgamation of arc-related terranes known as the Arabian-Nubian Shield. Importantly, sediments of the Tambien Group conformably transition into glacial deposits of the Sturtian Glaciation. This rare depositional environment created a unique stratigraphic sequence that contains horizons of both carbonate (on which isotopic measurements can be made) and volcanic ash (which can be precisely dated to temporally calibrate the stratigraphy) throughout the stratigraphy, as well as preserves the transition from an ice-free to a globally glaciated world. Such a stratigraphic sequence had not been identified anywhere in the world prior to our group's work on the Tambien Group. This combination of lithologies and the completeness of the stratigraphy allow us to develop paired geochronologic and chemostratigraphic (carbon and strontium isotopes, proxies for the global carbon cycle and weathering fluxes respectively) data from Tambien Group outcrops, which we use to constrain the relationships between the initiation of the Sturtian Glaciation, perturbations to the carbon cycle, and evolving weathering fluxes of the time.

Prior to this project, work to-date in the Tambien Group had been limited to exposures on the highlands west of the Danakil Escarpment in northern Ethiopia (known as the Tigray region) – vast areas of Tambien Group exposure east of this escarpment (known as the Afar region) remained unexplored (Fig. A). Furthermore, stratigraphic relationships and geochronological data that we had developed from Tigray suggested that basin initiation in this area youngs to the east (i.e. the stratigraphy gets younger eastward). It therefore followed that there were vast areas in the Afar that contain not only new exposures of pre- and syn-Sturtian Glaciation stratigraphy, but also the best possibility of encountering post-Sturtian Cryogenian interglacial stratigraphy, which had yet to be discovered in the region.

Therefore, in November and December 2018, we set out to perform first-order mapping and stratigraphic work in the Afar near a small and remote town called Sarea. During our time in the field, our team mapped these exposures in high detail to understand the tectonic history and stratigraphic framework of the study area, measured several stratigraphic sections to infer the evolution of the depositional environment during the Tonian era, and collected numerous

tuff/ignimbrite and carbonate samples for geochronologic and stable isotopic analyses respectively (Fig. B).

Preliminary correlation of stratigraphic units based on similar sequences of lithofacies between the Afar and Tigray suggest that initial Tambien Group sediments were deposited in the Afar tens of millions of years after initial Tambien Group sedimentation just to the west of the Danakil Escarpment. If true, this field observation would suggest deposition in a back-arc basin experiencing eastward slab rollback, consistent with younger stratigraphy to the east. We are currently in the process of preparing our new geochronologic samples for analysis, which, when complete, will provide quantitative constraints to test this field interpretation. In addition, geochronologic work in the Arabian-Nubian Shield as a whole has been limited, and so our understanding of the timing and nature of basin development, arc volcanism, and terrane amalgamation in this area remains sparse. Our new geochronologic samples will also shed additional light on these tectonic questions.

Our work near Sarea also revealed vast exposures of pre-Sturtian Glaciation stratigraphy, much of which was comprised of carbonate lithologies. We are also currently in the process of preparing samples collected from these carbonates for carbon and strontium analyses. When paired with the geochronologic samples that we collected from ashes interbedded with these carbonates, the isotope data will continue to improve our understanding of the timing, rate, and magnitude of perturbations to the global carbon cycle and weathering fluxes during the lead up to the Sturtian Glaciation, and create further insight into the relative importance of various conditions and feedback mechanisms (e.g. silicate weathering and volcanism) on initiating global glaciation.

Unfortunately, however, we found that the post-depositional tectonic and erosional history of the study area was such that the youngest Tambien Group exposure near Sarea pre-dates the onset of the Sturtian Glaciation by at least a few million years. This limitation prevents us from placing new constraints on syn- and post-Sturtian Glaciation processes. Nevertheless, as described above, the new exposures of pre-Sturtian Glaciation stratigraphy near Sarea that we were able to study due to the Lewis and Clark Fund already has and will continue to yield important constraints on the environmental context leading into the time period within which multicellular animals emerged. Furthermore, there remains vast areas of unexplored Tambien Group exposure in the Afar, where there is still the possibility of encountering post-Sturtian interglacial stratigraphy.

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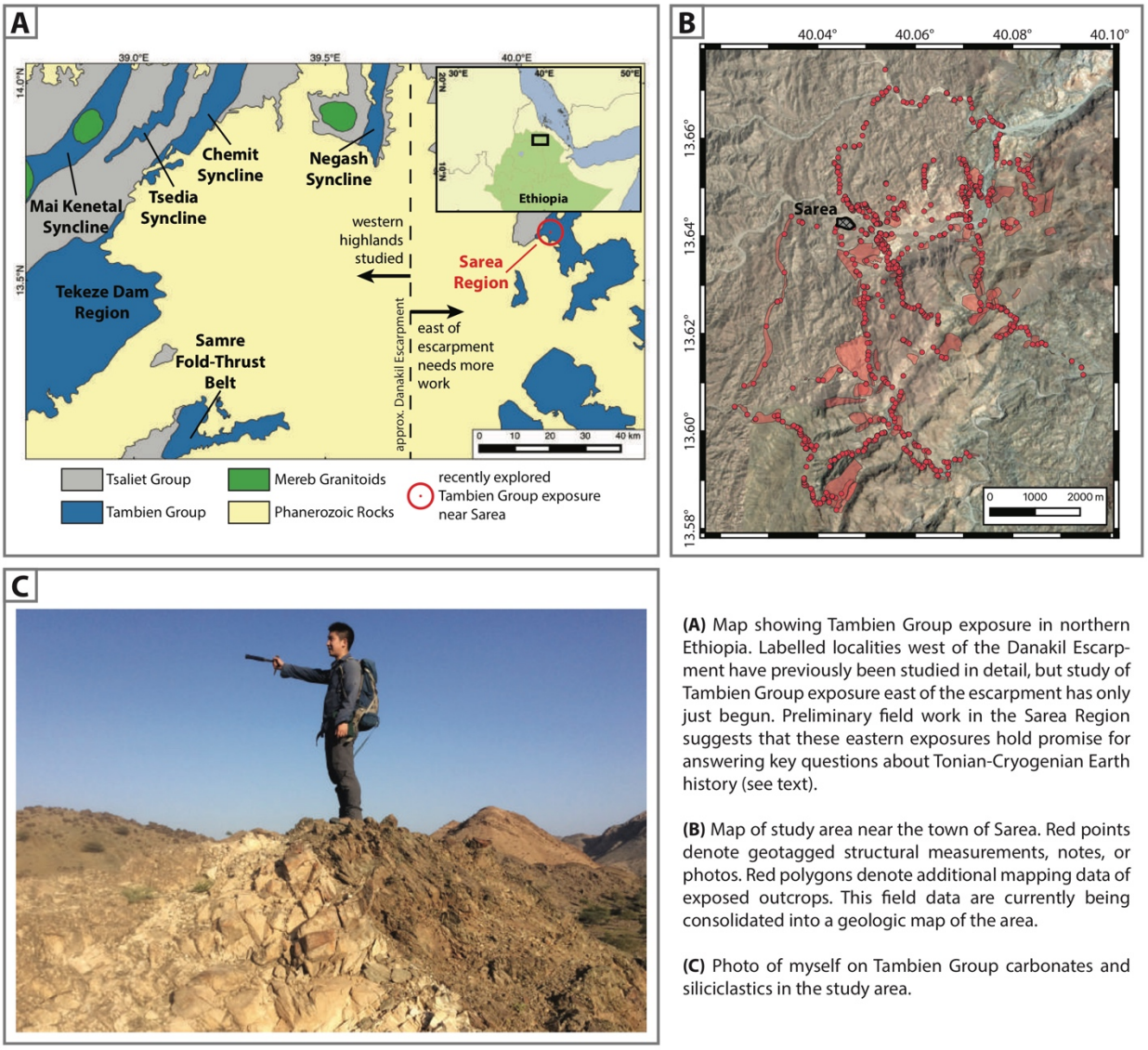

(A) Map showing Tambien Group exposure in northern Ethiopia. Labelled localities west of the Danakil Escarpment have previously been studied in detail, but study of Tambien Group exposure east of the escarpment has only just begun. Preliminary field work in the Sarea Region suggests that these eastern exposures hold promise for answering key questions about Tonian-Cryogenian Earth history (see text).

(B) Map of study area near the town of Sarea. Red points denote geotagged structural measurements, notes, or photos. Red polygons denote additional mapping data of exposed outcrops. This field data are currently being consolidated into a geologic map of the area.

(C) Photo of myself on Tambien Group carbonates and siliciclastics in the study area.