Linking the Central Atlantic Magmatic Province and the End-Triassic Extinction Through Carbon Isotope Measurements

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INTRODUCTION

According to Davies (2018), The Central Atlantic Magmatic Province (CAMP) is "one of the world's most expansive large igneous provinces", made up of dykes, sills, and flows in continental rift basins of Pangea at ~201 Myr (201 million years) (Davies, 2018, p. 2). This research project is special because a part of CAMP is located in our backyard, the Panhandle.

There are five major mass extinctions in Earth's history, and several of them "coincide with the appearance of igneous provinces" (Head, 2013, p. 47). The End-Triassic extinction is "one of the Phanerozoic's largest mass extinctions" and occurred at an estimated 201.564 Myr ago (Davies, 2017, p. 1-3). The End-Triassic extinction is "typically attributed to the climate change associated with [...] the Central Atlantic magmatic province" due the fact that CAMP volcanism and the ETE were found to occur at about the same time (Davies, 2017). During a volcanic event, CO_2 is generated by metamorphism, where magma intrudes and heats up adjacent rocks (Ramos, 2020). To measure the amount of carbon released from a volcanic event, we use carbonation and decarbonation reactions.

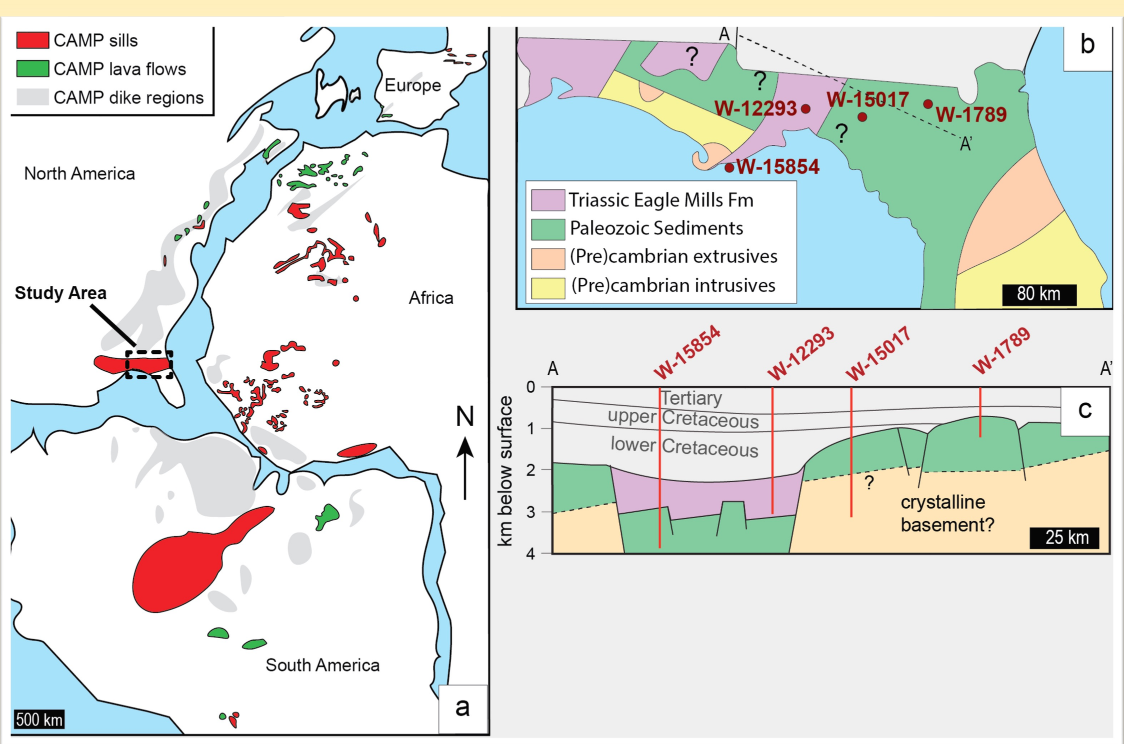


Fig. 1. CAMP in initial formation and modern day locations.
- Central North Atlantic Ocean
- Northwest Africa
- Southwest Europe
- Northeast South (Nova Scotia)
- Southeast North America (North Florida)

(Fig. 1. Schobben, 2019).

ABSTRACT

This research paper works to observe the connection between the large igneous province, the Central Atlantic magmatic province (CAMP), and the mass extinction, the End-Triassic extinction (ETE). We believe this large igneous province (LIP) is a main cause of this specific mass extinction because in geological history, LIPs have been shown to be a trigger of mass extinctions. To study this mass extinction, we are using the geological records from the Florida Geological Survey, located of the Panhandle of Florida. By measuring the amount of carbon released from the samples and creating models of CO2 released at certain temperatures and compositions, we can come closer to knowing if the magma intrusions specific to CAMP caused the End-Triassic mass extinction.

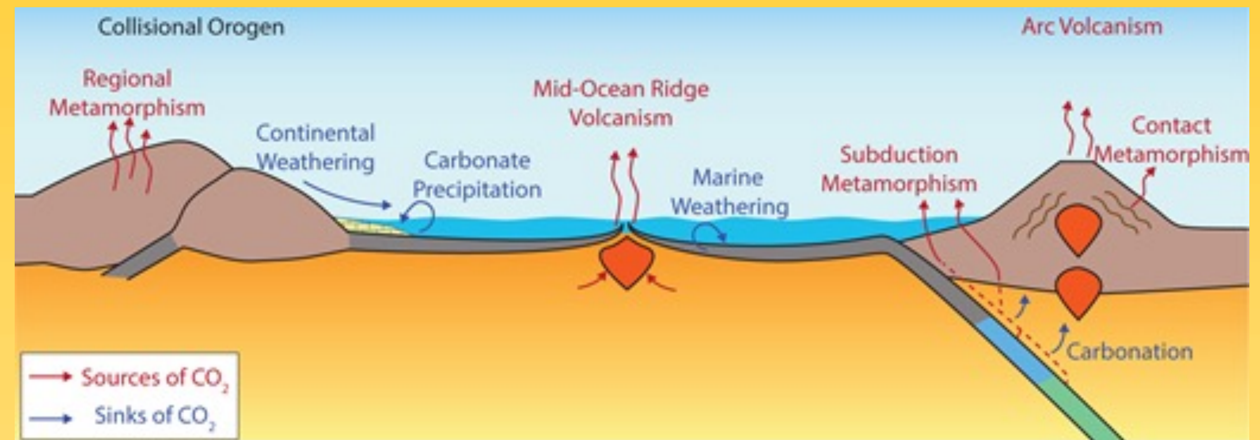


Fig. 3. Decarbonation and carbonation reactions (Stewart, 2019).

CO_2 SINKS AND SOURCES

Carbonation is "a major sink for atmospheric CO2", meaning the reaction takes CO2 from the atmosphere and creates a solid carbonate, aka sedimentary and metasedimentary rocks. (Stewart, 2019, p. 1370-1371). Decarbonation is a major source for atmospheric CO_2 and "occurs when a rock containing carbonate minerals [...] is metamorphosed at elevated temperatures and pressures. (Stewart, 2019, p. 1370). Without these processes, life on Earth could not exist (Stewart, 2019, p. 1369). In Ramos's (2020) study, they found that decarbonation within the ring of an igneous intrusion produces significantly more CO_2 than assimilation of the host rock by intruded magma (Ramos, 2020, p. 8). Because the volcanism event occurs in a geologically brief period of time, this was an important observation because it provides an explanation as to how extreme carbon release could occur.

Through the carbonation and decarbonation reactions, we can estimate carbon isotope excursion, which is an episode of massive carbon release and is a measurable way to understand the effects of global temperatures rising or falling. For example, "the ETE is associated with a global ~-3.6% negative carbon isotope excursion", which associated with global warming of 3-4 degrees C. (Davies, 2017, p. 2, Heimdal, 2019, p. 1). Additionally, "the inferred initial pulse of CO2 (and other gases) coincides with floral and faunal" extinction, further supporting the connection between these events (Hesslbo, 2002, p. 253).

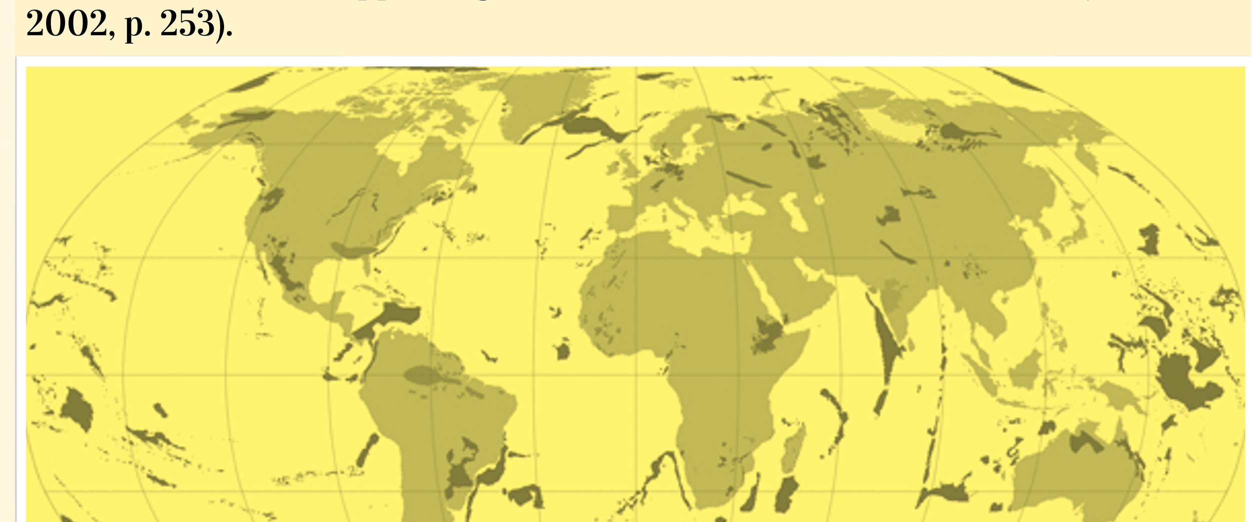


Fig. 2. Purple depicts CAMP. Large igneous provinces (LIPs) are shown. While the formation of these LIPs is spread out over all of Earth's history, they all cover millions of square kilometers, are comprised of basalt, a common iron- and magnesium- rich rock, and formed "quite swiftly" in geological time (Head, 2013, p.42).

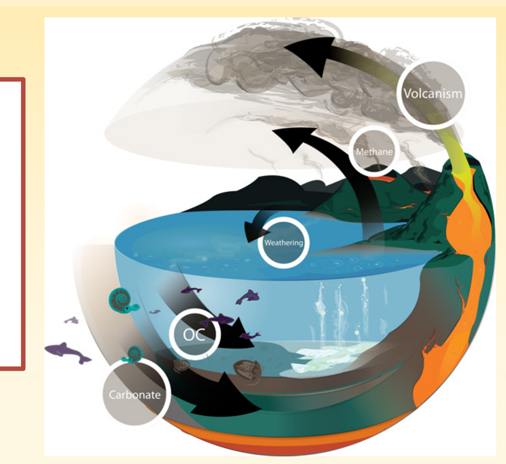
METHODS

- Using the Florida Geological Survey Greenbook Index and Florida Geological Survey Thin Section database. Focused on counties in the panhandle: Columbia, Taylor, Levy, Leon, Franklin, Jackson, and Madison. This Greenbook index includes W numbers for rockslides.
- Using Theriak-Domino software. This software is used to calculate and plot thermodynamic functions, equilibrium assemblages, and rock-specific equilibrium assemblage diagrams. This program approaches equilibrium by means of Gibbs free energy minimization (de Capitani, C., and Petrakakis, K., 2010)
- Reading published scientific papers relating to mass extinctions, large igneous provinces, and metamorphic decarbonation.

RESULTS

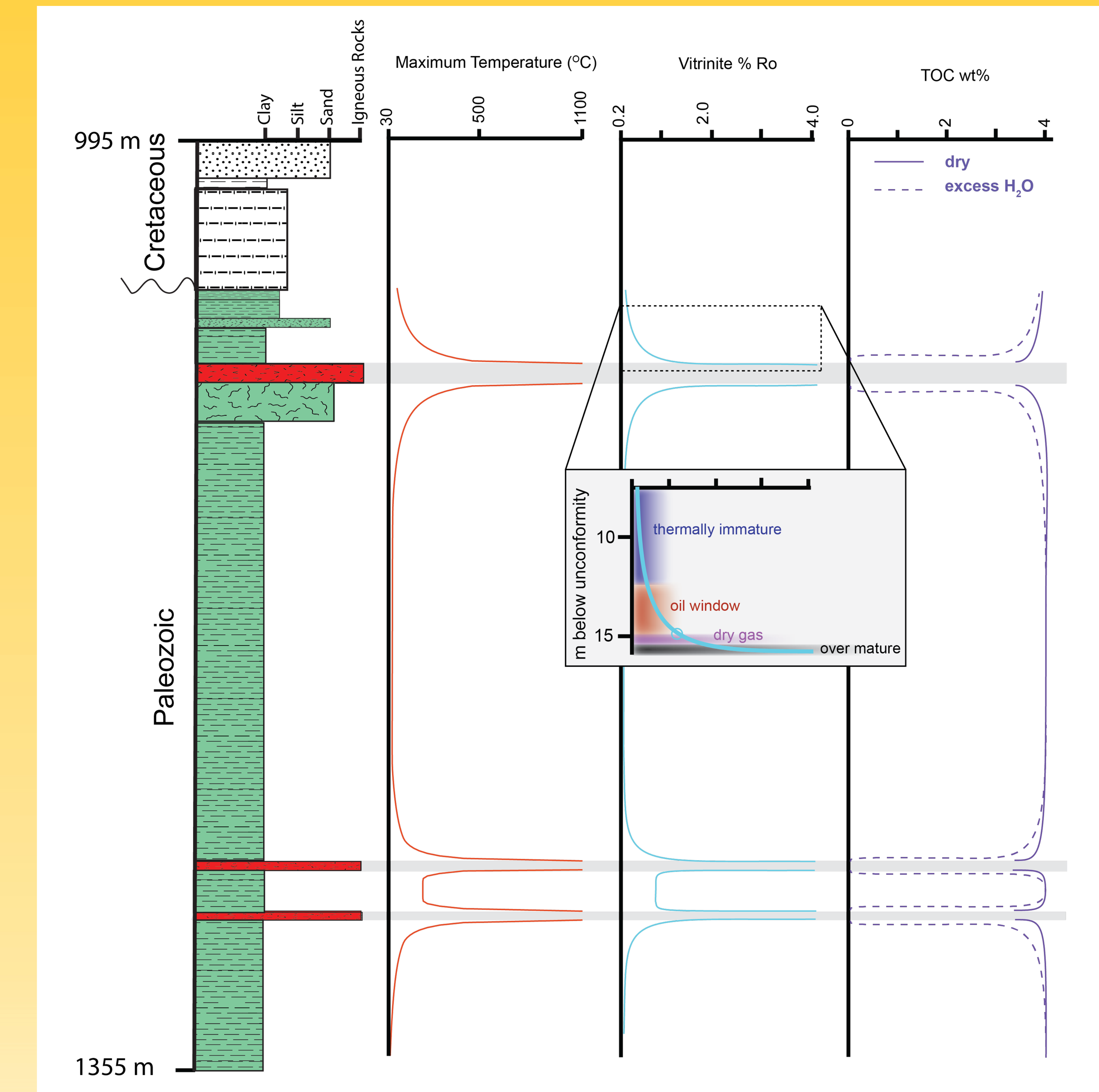
- The chemical makeup of the samples are based on upper- and lower-Paleozoic rocks we found using the Florida Geological Survey Greenbook Index.
- While the carbon release results for this project are pending, we expect to either prove or disprove what has been modelled in studies such as Heimdal (2018) and Stewart (2019).
- Heimdal provided models of rock samples from the Amazonas Basins (a part of CAMP located in North East South America) to estimate thermal effects of the rocks at high temperatures over the geological timeframe. These models show that "temperature and vitrinite reflectance values increase, whereas the total inorganic carbon content decreases" towards where the sill intruded (Heimdal, 2018, p. 5).
- Another model in this study shows cumulative CO_2 production and peak fluxes of CO_2 production from contact metamorphism of the same sills from the Amazonas Basins, yielding a "production of 88,000 Gt CO2", half being organic CO2 and half inorganic (Heimdal, 2018, p. 7). We can use this value to find the carbon isotope excursion for this specific period of time; it was a δ 13C drop of ~3%.
- One way to approach understanding this value is to compare it to an observed mass extinction triggered by volcanism. The Siberian Traps were also observed to have a brief, large negative carbon isotope excursion near the End-Permian mass extinction (Newby, 2021, p. 680).

Fig. 4. Carbon cycle (Schobben, 2019)
- Carbonate
- Organic Compounds (OC)
- Weathering (silicate)
- Methane
- Volcanism



DISCUSSION

- The results shown in Model 1 produced by our Theriak-Domino program support models found in Heimdal's study for the Amazonas Basins. This is an important observation because it provides evidence for perturbations to the global carbon cycle during the End-Triassic Extinction. The models by Heimdal (2018) are instrumental in theoretically finding how much CO2 could have been released during the onset of the CAMP volcanisms, and our research will work to observationally understand the amount of CO2 released by performing decarbonation tests on rock samples from the Central Atlantic magmatic province.
- As more research is performed on the CAMP volcanism and its relation to the ETE, models of the past have been found to underestimate the amount of CO2 released (Heimdal, 2018). Our model provides further study into the amount of CO2 released during CAMP volcanism. Proving the cause of the CIE associated with CAMP could demonstrate a causation between the magma intrusions and the End-Triassic mass extinction, something that has not yet been observed, only theorized.
- If the CAMP volcanisms acted the way our models and other researchers' models show, then the amount of CO2 released would be significant enough to alter the global climate and cause a mass extinction. This work is important because understanding past carbon cycles catastrophes gives us better insight into modern human-driven climate change.



Model 1. Total organic carbon percentage lost using Theriak-Domino software.

CONCLUSION

Understanding Earth's geological history could be fundamental in reversing anthropogenic climate change. Discovering what exactly caused the End-Triassic mass extinction helps to understand the negative feedback carbon cycle that keeps our Earth habitable, and as one of the largest mass extinctions, this is critical information. The models we created support a negative carbon isotope excursion near the ETE, and future observation through decarbonation reactions will either prove or disprove these models.

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