Our knowledge of Earth history is controlled by our ability to make age determinations on rock. This provides a context for all geological observations and interpretations. These age determinations are made using radiogenic isotopes, specifically of uranium changing into lead through the process of radioactive decay. This decay process occurs at a fixed rate, enabling us to make age calculations. The ability to measure these isotopes of uranium and lead on a mass spectrometer allow us to calculate the age of a rock. These isotopes of uranium and lead can only be found in significant quantities in specific minerals. However, each of the minerals has both strengths and weaknesses in providing age determinations. All these minerals generally record the age at which they formed, as this is when their crystals allow both lead and uranium into their crystal structure. However, these minerals also have temperatures when the isotope system may still be disturbed after crystallisation (i.e., the closure temperature of the mineral). Many minerals have a low closure temperature, therefore heating above 500°C (in the case of apatite), will reset the radiogenic isotopes, and therefore the age. These low temperature U-Pb geochronological studies on apatite will be the focus of this project. Additionally, magnetisation of the rock is principally controlled by the mineral magnetite. However, the re-magnetisation (Curie) temperature, is similar to that of apatite. The ability to date apatite, therefore, can provide clues as to the primary or secondary magnetic information preserved in rocks.

In the Phanerozoic (since 540 million years ago), generally, there is less of a problem in thermal disturbance in the rocks. Before this time, almost all rocks have undergone at least some alteration due to changes in temperature and pressure (metamorphism), or simply have been destroyed. These changes have the ability to effect spatial and temporal knowledge of the world at this time, recorded by paleomagnetism and geochronology. Sometimes, many assumptions are made as to whether a rock is primary or secondary in the literature. Much of the focus in our knowledge has been on the primary processes, ignoring the secondary alteration. However, secondary processes can affect these primary processes by isotopic disturbance (in geochronology) or remagnetisation (in paleomagnetism), and this will be studied herein.

Studies will be done mostly on the mineral apatite, which will be readily obtained from mafic dykes and sills. Dykes and sills provide excellent recorders of when (geochronology) and where (paleomagnetism) they formed on Earth. They are the preserved remnants of ancient volcanic eruptions. These dykes and sills are widespread globally, especially in the ancient cores of the continents, which are called cratons. Therefore, these cratons provide a type of ‘window’ into Earth history. The mafic dykes and sills of the Kaapvaal Craton in southern Africa will form the focus of this study, as it is a relatively pristine and well preserved piece of Precambrian (greater than 540 million years ago) crust.

In this project, we will study the effects that lower-temperature U-Pb geochronology can have on high-temperature U-Pb geochronology and paleomagnetism on the Kaapval Craton, projects one and two. This will allow us to assess the validity of data and interpretations made in previous studies on the craton. If a metamorphic event is high enough in temperature reset the primary isotopic composition in apatite, then it can also re-set the magnetisation present in the rock. Testing this will be the first objective in this study. Additionally, isotope disturbance by metamorphism creates discordance, and can affect the age of a rock by changing the isotopic ratios that control the determination of the age of the rock. This will be the second objective to test in this study. In the case of simple disturbance by one event, knowing the age of this younger event can help us to constrain the ‘true’ age of the rock unit better.

Two additional case studies (projects three and four) assessing the thermal impact of two cataclysmic events on the Kaapvaal Craton will also be made in this project. These events include the Bushveld Complex, the biggest layered intrusion on Earth, and the Vredefort Dome meteorite impact, the largest and oldest known meteorite impact event on Earth. These events shaped the craton, but their influence over the larger craton is poorly understood. Using combined crystallisation ages from baddeleyite in mafic rocks, and cooling ages in apatite, the exact extent of these events over the craton will be assessed. This knowledge will give us better control on the spatial and temporal context of the Kaapvaal Craton in Earth’s history.