MINIMUM AGE AND PROVENANCE OF THE CORRELATED THOMSON AND ROVE FORMATIONS OF EASTERN MINNESOTA

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INTRODUCTION

The correlated Thomson and Rove Formations are exposed as heterogeneous formations composed of greywacke, slate, sandstone, and argillite in Northeastern Minnesota as part of the Animikie Group (Morey, 1970). Other members of the group include the Kakabeka and Pokegama Quartzites (mature quartz arenites made from quartz sand and mud with a basal conglomerate that separates it from the underlying Lower Precambrian granites and volcanic-sedimentary rocks of Northeastern Minnesota) and The Biwabik Iron Formation (which underlies the Thomson Formation) and the Gunflint Iron Formation (which underlies the Rove Formation) (Ojakangas, 2004). The Thomson and Rove Formations are overlain unconformably by Keweenawan basal conglomerates (the Nopeming and Puckwunge formations, respectively). The Penokean orogen is a large orogenic belt extending from Minnesota south to Iowa which resulted when a volcanic arc was accreted to the southern margin of the Superior craton (Boerboom, 2005). Over time it has been divided into many different temporally spaced events and geographical regions by different researchers. The Animikie basin is generally considered the northernmost manifestation of the orogen. It is thought of as a northward-migrating foreland basin which formed to the north of the Penokean fold-and-thrust belt (Boerboom, 2005). The Thomson and Rove Formations are composed of greywackes which are in places fairly mature sandstones and in other areas finely bedded argillite. The dominant phase is called a slate because the thin beds have been recrystallized to the point that they do not disintegrate to clay like common shale slabs. They were deposited in a marine environment and are characterized in places by turbidites (Morey, 1970). The top and bottom contacts of the Thomson are not exposed, and the Rove is exposed in sections that have been pieced together to create the probable stratigraphy of the whole. The deposition of the Rove Formation has been dated previously to 1836 ± 5 Ma using ID-TIMS (isotope-dilution thermal ionization mass spectrometer) on a single zircon and to a mean age of 1827 ± 8 Ma using SHRIMP (sensitive high-resolution ion microprobe) for 15 analyses. All of the zircons for these analyses were obtained from interbedded tuff layers (Kissin, 2003).

Sample Preparation/ Analytical Techniques

Two samples were analyzed in this study. Zircons were taken from the sample using traditional zircon separation techniques: chipmunk machine, disc mill, Wifley table, magnetic free-fall, heavy liquids, and Frantz Magnetic Separator. The zircons were then chosen by hand and mounted in an epoxy puck and polished. A ThermoFinnigan Element2 magnetic sector double focusing ICP-MS coupled with a New Wave Research UP-213 laser system at the research lab at Washington State University was used to date each zircon. The spatial resolution is 30-60μm. A blank is measured between each sample unknow and Peixe and FC1 standard zircons were measured after every 10 analyses to check isotope fractionation. The beam size of th is 30μm-40μm and the crater that is produ by the laser on the surface of the zircon is usually about 25μm deep. The detrital zir in these samples will be typically ~160 μn x ~40μm x ~40μm. The typical error of th U-Pb determinations is about 2-3%, which the standard deviation of the results achiev through repeated measurements of the sam standard zircon. See Chang, 2004 and Ch 2006 for further discussion. For larger zir with obvious zoning, two readings were ta one of the rim and one of the core. For sm zircons with obvious cores, the rims were The zircon analyses yielded three separate U^{238}/Pb^{207}, U^{235}/Pb^{206} and Pb^{206}/Pb^{207}. The r presented here are those in which the dates less than 10% discordant, which compromi 73 analyses for the Rove Formation and 62 analyses for the Thomson Formation.

RESULTS

There were zircons in the sample represent euhedral, subhedral, and rounded forms, as well as zircons which appeared jagged and broken. Most of the zircons in this sample between 40 and 200μm. There seemed to l correlation between the physical appearanc the zircon and its age. Most zircons contai many pits and cracks and thus in all but a few cases only one spot could be used for analysis. The majority of the zircons analyzed are between 1800 and 2000 Ma. Those analyses that fall into this age range are spread evenly and fail to fall into separate, distinct populations. These paleoproterozoic dates correspond to the ages that have been previously found in ash layers of the Rove Formation, and thus must be derived from slightly older or geologically contemporary igneous bodies (Kissin, 2003). The Wisconsin magmatic terrane could be a candidate, but it does not

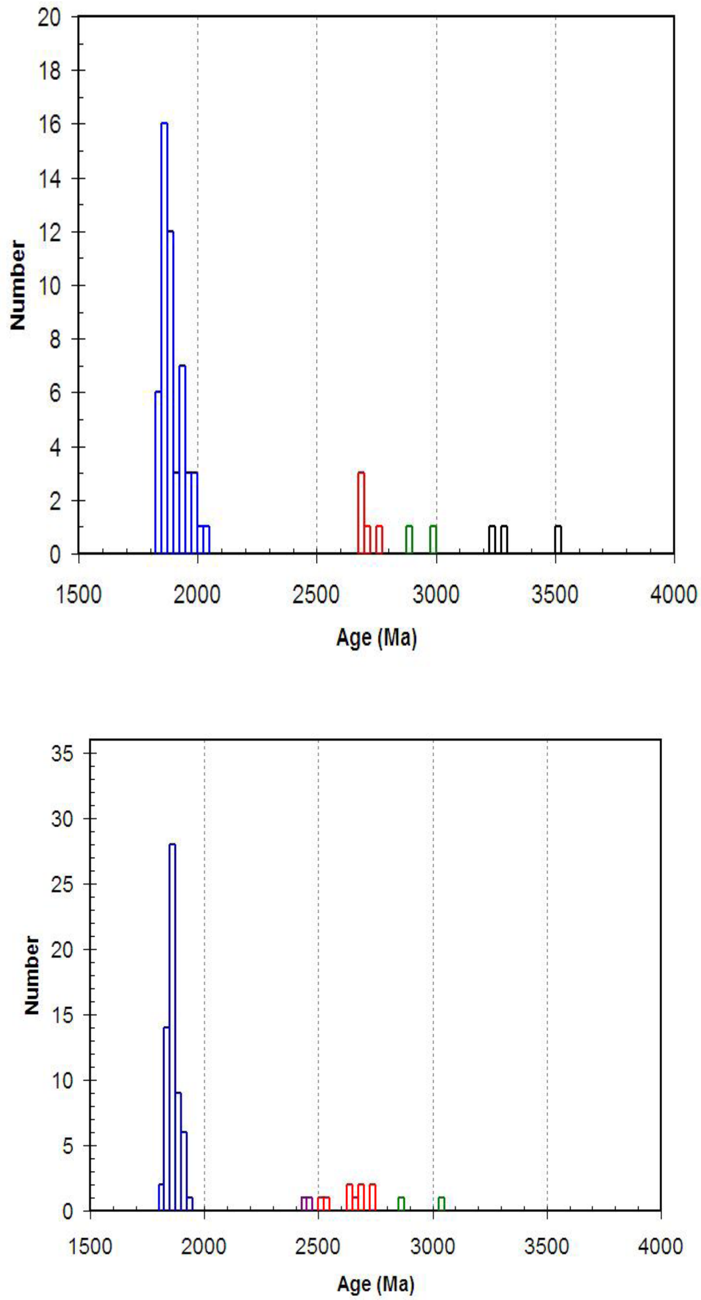

Figure 1. Binned (25 Ma) frequency histograms of detrital zircon ages for (a) the Thomson Formation and (b) The Rove Formation

agree with the paleoflow, which was determined to be from north to south (Ojakangas, 2005; Morey, 1970). These grains could have also come from sources in the Rae Domain in Nunavut, Canada, such as the Hudson granites (1.85-1.81 Ga), or other various granitic plutons (1.87-1.85, 2.0-1.9 Ga) (Berman, 2005). These are possible, but less likely because they would have to be transported a greater distance. The older zircons in the

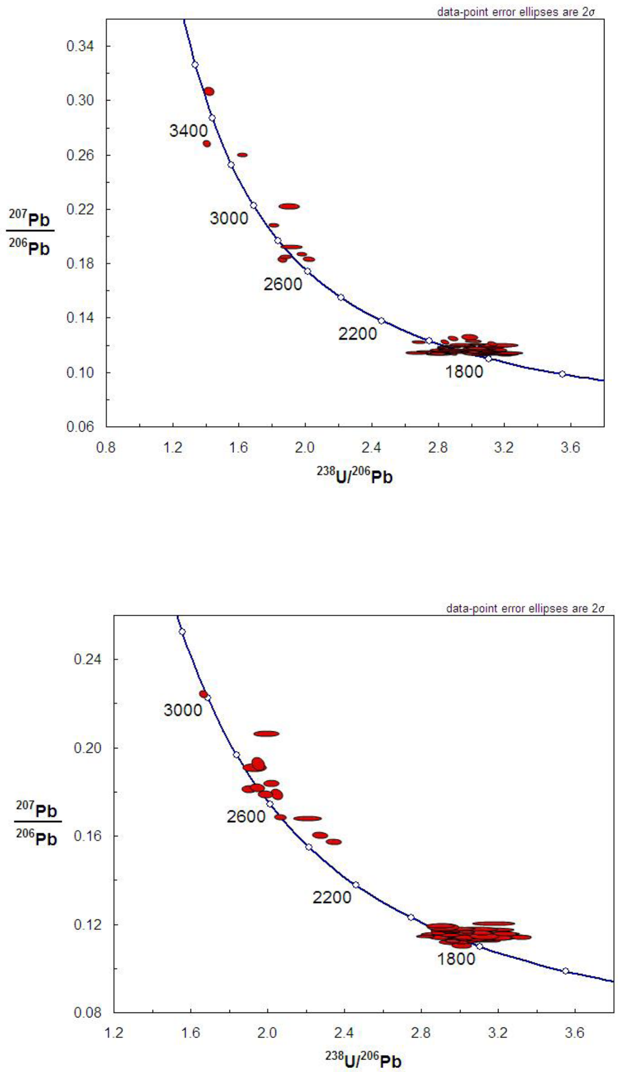

Figure 2. Tera-Wasserberg Normal Concordia plots showing data with 2σ envelopes (bottom) for (a) the Thomson Formation and (b) the Rove Formation.

age range could also be attributed to the 2.0-1.9 Ga Thelton-Taltson Orogeny. Another likely source for these zircons is magmatic activity associated with the Trans-Hudson Orogeny, which took place between 1840 and1880 Ma.(Bickford et. al, 2005) There are no zircons in the age range between 2431 and 1938 for the Rove Formation and between 2679 and 2034 for the Thomson Formation. Hemmings et al. (1995), cited the source ages for the Thomson Formation as ~2100 and the source ages for the Rove Formation as between 2200 and 2600. It appears likely that this number represents an average between the younger paleoproterozoic grains and those of the archean basement. A small population of zircons, unique to the Rove Formation, is found between 2400 and 2600 mya. These zircons might come from a northern source that was not carried far enough south to appear in the Thomson Formation, possibly the northwest Superior Province at Crying Lake, where igneous sources have been dated from 2.8 to 2.3 Ga (Böhm et al., 2000). In both formations there are dates between 2600 and 3000. These may have been derived from the nearby Wabigoon terrane, which has the following igneous rocks and dates: Winnipeg River Terrane (<3320 Ma), Marmion Batholith (3000 Ma), Western Wabigoon Terrane (2800-2700 Ma); The Falcon Lake Island ultrapotassic pluton (2695±3 Ma), a granodiorite sill separating the Lake of the Woods Greenstone belt and the Winnipeg River subprovince (2709± 4Ma) (Tomlinson, 2004; Ayer, 2000). The Winnipeg River subprovince gneissic sodic group is 2830-3170 Ma; it is intruded by potassic plutons from 2660-2709Ma (Ayer, 2000). The Black Pic monzodiorite has been dated to 2689±2Ma, the Loken Lake Pluton to 2687±2Ma, some foliated granite in the area to 2680±2Ma, the Nama Creek pluton to 2680±2Ma, the Banana Pluton to 2677±2Ma, and the Everest Lake Pluton to 2679±2Ma (Zaleski, 1999). These are favorable source areas because of their proximity to the Animikie basin (they are located on the north side of present-day Lake Superior in Canada). Ages older than 3030 Ma are only present in the Thomson Formation, suggesting that they may originate from a southerly source, perhaps some of the older rocks of the Minnesota River Valley. The Morton, Montevideo, and McGrath gneisses all fit into this age range and are located to the south of the Thomson Formation.

In summary, the two formations seem to be derived from a great variety of sources and yielding zircons with a variety of morphologies. It is possible that there are age ranges present in the formation that are not represented in the sample, due its limited size. Similarly, the maximum age of deposition cannot be absolutely constrained because there is no certainty that this sample contains the youngest zircon present in the formation, but a preliminary constraint on the minimum age can be made. The average of the youngest five zircons in each formation constrains the maximum depositional age at 1841.3 Ma with a maximum 2σ error of 15.7 Ma for the Thomson Formation and 1826.2 with a maximum 2σ error of 16.1 Ma for the Rove Formation.

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