PROVENANCE ANALYSIS OF THE MARQUETTE RANGE SUPERGROUP SEDIMENTARY ROCKS USING U-PB ISOTOPE GEOCHEMISTRY ON DETRITAL ZIRCONS BY LA-ICP-MS

REBEKAH LUNDQUIST
Carleton College
Sponsor: Cameron Davidson

INTRODUCTION

A variety of recent advancements in the development of high-resolution U-Pb dating techniques of detrital zircon have allowed detailed studies of Precambrian sedimentary rocks (e.g. Van Wyck and Norman, 2004; Pufahl and Fralick, 2004; Medaris et al., 2005). Provenance studies utilizing these new dating methods can provide valuable insights into the depositional environments of these rocks which in turn help describe the tectonic evolution of the Lake Superior region. In this contribution, I 1) present new LA-ICP-MS (Laser ablation inductively coupled plasma mass spectrometry) U-Pb age dates from detrital zircons contained in the sedimentary Palms and Tyler Formations of Wisconsin and Michigan, 2) correlate these ages with intrusive and/or thermotectonic (zircon forming) events, and 3) attempt to constrain the provenance of these formations.

STUDY AREA

This study primarily focuses on the metasedimentary units of the Marquette Range Supergroup (MRS) of the Gogebic and Marquette Ranges. The MRS is a Paleoproterozoic continental margin assemblage that lies unconformably upon the southern margin of the Archean Superior craton in northern Wisconsin and Michigan. The MRS includes, from oldest to youngest, the Chocolay Group, a shelf marine facies, the Menominee Group, turbidites passing up into banded iron formation and the Baraga Group, a sequence of shales and turbidites (Fig. 1, Craddock et al., this volume; Ojakangas et al., 2001). Of these units, I sampled the Palms Formation (KP05-42), a fine-grained quartz arenite from the Menominee Group, and the Tyler Formation (KP05-40), a fine-grained quartz arenite from the Baraga Group (Figs. 1&2, Craddock et al., this volume).

DETRITAL ZIRCON RESULTS

LA-ICP-MS zircon dates for the Palms and Tyler Formations are summarized in Table 1 and plotted in Figures 1 & 2. For this study, zircon analyses less that 10% discordant are considered concordant, and all reported dates are $^{207}Pb/^{206}Pb$ ages.

Palms Formation

The Palms Formation yielded 111 concordant grains that define three groups separated in frequency and age (Fig. 1). The histogram in Figure 1B shows one major cluster of analyses (n=108) of Neoarchean dates between 2664 and 2830 Ma with a concentration of dates at ca. 2706 Ma. Only represented by 2 grains, a Mesoarchean date of ca. 3523 Ma is present, and one grain yielded a date of 2594 ±12 Ma, the youngest age represented in this data set.

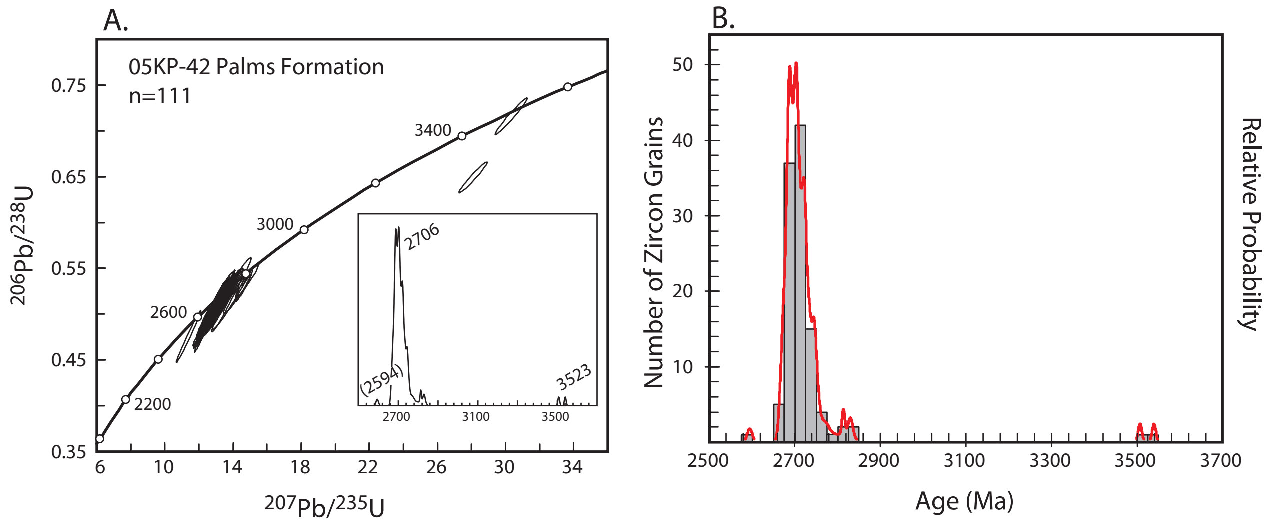

Figure 1. U-Pb dates of detrital zircons from the Palms Formation (KP05-42). A) Concordia diagram with inset showing relative probability distributions from (B). Ages (Ma) assigned to peaks derived from Unmix Ages modeling (Ludwig, 2001). B) Probability density distribution-histrogram plot showing distribution of $^{207}Pb/^{206}Pb$ ages. Errors for individual analyses are <10% discordant; n = number of individual grains analyzed.

Stratigraphic Unit/Area	Sample #	Major Zircon Age Populations (Ma)§	Youngest zircon grains (Ma)†	Maximum depositional age‡
Palms Wakefield, MI*	05KP-42	2706, 3523, 2594	2594 ± 12 (1)	Neoarchean
Tyler Hurely, WI*	05KP-40	1850, 2665, 2949, 2023, 2042, 3168	1818 ± 15 (10)	Paleoproteroizic

*Detrital zircon sample locations. (Palms: UTM Zone 16T, Easting 275471, Northing 5151275. Tyler: UTM Zone 15T, Easting 715350, Northing 5149709. NAD27 Conus Datum).

§ Age populations to nearest m.y. listed in order ot decreasing relative abundance.

† 207Pb/206Pb ages and errors; number of grains in parentheses.

‡ Depositional age constrained by youngest discrete zircon age population.

Table 1. Summary of detrital-zircon ages, Marquette Range Supergroup, Lake Superior Region, U.S.A.

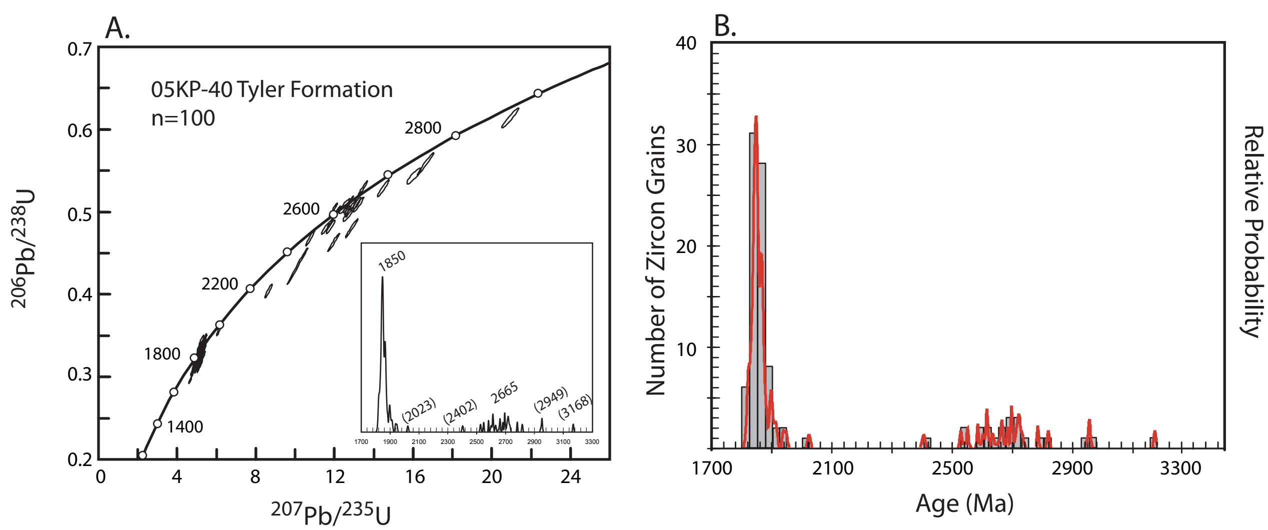

Figure 2. U-Pb dates of detrital zircons from the Tyler Formation (KP05-40). A) Concordia diagram with inset showing relative probability distributions from (B). Ages (Ma) assigned to peaks derived from Unmix Ages modeling (Ludwig, 2001). B) Probability density distribution-histrogram plot showing distribution of $^{207}Pb/^{206}Pb$ ages. Errors for individual analyses are <10% discordant; n = number of individual grains analyzed.

Tyler Formation

The Tyler Formation yielded 100 concordant grains and contains several populations of detrital zircons (Fig. 2). Most of the zircons (n=76) have Paleoproterozoic dates between 1818 and 1938 Ma with the youngest date at 1818 ± 15 Ma. The well-defined peaks of the histogram (Fig. 2B) show the highest concentration at ca. 1850 Ma. A second cluster is represented by 18 grains with dates between 2525 and 2815 Ma with an average Neoarchean age of 2665 Ma. The analyses in this range tend to fall either on concordia or slightly below (Fig. 2). Additional ages of 2949 (n=2), and 2023, 2402, and 3168 Ma, are also present in this sample.

PROVENANCE INTERPRETATION

Palms Formation

The U-Pb age spectrum for the Palms Formation (Fig. 1) show that these rocks are dominated by Neoarchean zircons (ca. 2706 Ma) with a minor Mesoarchean input. The youngest zircon yields an age of 2594 ± 12 Ma which indicates a maximum age of deposition to be Neoarchean.

These detrital zircon ages are largely consistent with what is known about the age of Archean basement rocks in the Superior Province (Fig. 3). Specifically, some of the dates between 2664 and 2830 Ma present in the Palms Formation have been recorded in studies by Sims et al. (1980), revealing an age of 2735 ±16 Ma for the Puritan quartz monzonite, a pluton that intrudes the Ramsay Formation (mafic and felsic metavolcanic rocks) and crops out just south of KP05-42. Thus, the Archean Puritan quartz monzonite and related intrusions might represent a major component of the sediment source for the Palms Formation.

The Palms Formation also contains a

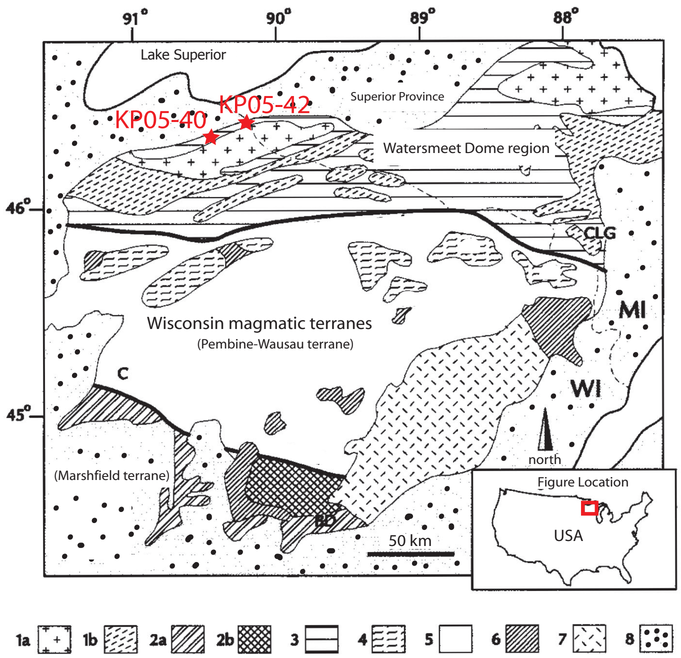

Figure 3. Generalized geologic map of the Wisconsin magmatic terranes in northern Wisconsin and Michigan, modified from Van Wyck and Johnson (1997) in relation to Sample locations of the Palms (KP05-42) and Tyler (KP05-40) Formations. 1-Archean basement of the Superior Province. 1a-Puritan Quartz Monzonite and the Northern Complex, 2735 ±16 Ma (Sims et al., 1980). 1b-High-grade gneiss basement (Watersmeet-type), 3400-3600 Ma (Bickford et al., 2006). 2-Marshfield terrane. 2a-Archean basement of the Marshfield terrane, 2550, 2680, 3000-3200 Ma (Van Wyck and Norman, 2004). 2b-Cover rocks of the Marshfield terrane, age uncertain. Both 2a and 2b are intruded by numerous Penokean synorogenic plutons (not shown), 1860 to 1835 Ma by Sims (1996). 3-Marquette Range Supergroup sedimentary deposits. 4-Gneiss domes developed south of the Niagara fault within the Pembine-Wausau terrane. 5-Volanic and lesser sedimentary rocks of the Pembine-Wausau terrane, intruded by numerous Penokean synorogenic plutons (not shown). 6-Alkali-granite and 1760 Ma granites (undifferentiated). 7-Wolf River batholith (1.5 Ga). 8-Cover younger than 1.5 Ga.

Mesoarchean age signature represented by two analyses of 3523 Ma. These ages correspond with geochronological data from tonalitic gneiss protoliths exposed in the Watersmeet Dome in northern Michigan yield dates between 3410 Ma and 3600 Ma (Bickford et al., 2006). Leucogranite dikes intruding the Watersmeet

Dome gneiss yield ages of ca. 2600 Ma (Van Wyck and Norman, 2004), which might explain the presence of the 2594 ± 12 Ma date in the Palms Formation.

Tyler Formation

The Tyler Formation is dominated by Paleoproterozoic grains of ca. 1850 Ma. This age is typical of igneous intrusive rocks that were emplaced in the Wisconsin magmatic terranes during the Penokean orogeny (Van Wyck and Johnson, 1997). In Wisconsin, the orogen has been divided into two terranes, a northern Pembine-Wasau terrane and a southern Marshfield terrane, both of which contain numerous Penokean synorgenic plutons (Fig. 3). Of these, the Marshfield terrane contains calc-alkaline plutons of granitic composition with age components ranging from 1860 to 1835 Ma (Sims et al., 1989, 1993). Therefore, these Penokean volcanics in the Wisconsin magmatic terranes represent the major component in the sediment source to the Tyler Formation. The maximum age of deposition for the Tyler Formation is 1818 ± 12 Ma. If folding of the Tyler Formation is related to Penokean deformation, then this age indicates that Penokean deformation may have lasted until at least 1818 Ma and not ca. 1835 Ma as suggested by previous studies (e.g. Schneider et al., 2002; Bickford et al., 2006).
The Tyler Formation also records Neoarchean ages ranging from 2525 to 2815 Ma with an average age of 2665 Ma, along with lesser input of 2949 and 3168 Ma grains. The source of these grains is most likely the high-grade gneiss and granite rocks of the Marshfield terrane (Fig. 3), which Van Wyck and Norman (2004) showed to contain zircons of 2550, 2680, and 3000 to 3200 Ma.

In addition, the Tyler Formation yields zircons from 2023 and 2402 Ma sources. These ages are significant yet problematic because there is no evidence for local derivation of these grains, since gneisses of these ages are unknown in the Wisconsin/Michigan region (Van Wyck and Norman, 2004). There are two interpretations for the provenance of these detrital data: either crustal rocks of this age do or did occur locally and have yet to be identified, or these grains were introduced to the Tyler Formation from terranes outside the Lake Superior region. In a study of detrital zircon ages of early Proterozoic quartzites in Wisconsin, Van Wyck and Norman (2004) posit the possibility that the source of 1.9-2.3 Ga zircons contained within the Baraboo quartzite could be explained by recent geophysical studies that indicate the southern limit of the Marshfield terrane is marked by an east-west lineament called the Trempealeau discontinuity (Cannon et al., 1999). The Trempealeau discontinuity could possibly separate the Marshfield terrane from distinct Pre-Penokean crust south of the discontinuity, which may well be the source of the 2023 and 2402 Ma grains within the Tyler.

CONCLUSIONS

LA-ICP-MS $^{207}Pb/^{206}Pb$ ages of detrital zircons from the Palms Formation indicate that this sedimentary unit was derived from Neoarchean basement rocks of the same age as the Puritan quartz monzonite and its correlative rocks with a Mesoarchean input from the high-grade gneisses of the Watersmeet Dome region. Detrital zircons within the Tyler Formation contain a major population of Penokean grains of ca. 1850 Ma with the youngest grain at 1818 ± 12 Ma, suggesting that Penokean deformation could have lasted until ca. 1818 Ma. The Neoarchean age of 2665 Ma, along with lesser input of 2949 and 3168 Ma grains, are from the high-grade gneiss and granite rocks of the Marshfield terrane.

This study proves the effectiveness of using LA-ICP-MS for detrital zircon geochronology to strengthen the stratigraphic and temporal relationships of Precambrian sedimentary units for the entire Lake Superior region as well as contribute to new interpretations of Precambrian tectonic history.

ACKNOWLEDGEMENTS

I thank Cameron Davidson, Karl Wirth, and John Craddock for advising and assistance. In gratitude I acknowledge Jeff Vervoort for help with the U-Pb dating and for access to the GeoAnalytical Lab at Washington State University. I thank MN Keck participants for help with sample collection and processing.

REFERENCES CITED

Bickford, M.E., Wooden, J.L., and Bauer, R.L., 2006, SHRIMP study of zircons from Early Archean rocks in the Minnesota River Valley: Implications for the tectonic history of the Superior Province: Geological Society of America Bulletin, v. 118, no. 1/2, p. 94-108.

Ludwig, K.R., 2003, Isoplot 3.00, a geochronological took-kit for Excel: Berkely Geochronology Center Special Publication 4, 67 p.

Medaris, L.G., Singer, B.S., Dott, R.H., and Johnson, C.M., 2005, Detrital Zircon Ages from Early Proterozoic Quartzites, Wisconsin, Support Rapid Weathering and Deposition of Mature Quartz Arenites: A Discussion: The Journal of Geology, v. 113, p. 233-234.

Ojakangas, R.W., Morey, G.B., and Southwick, D.L., 2001, Paleoproterozoic basin development and sedimentation in the Lake Superior region, North America: Sedimentary Geology, v. 141-142, p. 319-341.

Pufahl and Fralick, P.K., and Fralick, P.W., 2004, Depositional controls on Paleoproterozoic iron formation accumulation, Gogebic Range, Lake Superior region, USA: Sedimentology, v. 51, p. 791-808.

Schneider, D.A., Bickford, M.E., Cannon, W.F., Schulz, K.J., and Hamilston, M.A., 2002, Age of volcanic rocks and syndepositional iron formations, Marquette Range Supergroup: implications for the tectonic setting of Paleoproterozoic iron formations of the Lake Superior region: Canadian Journal of Earth Sciences, v. 29, p. 999-1012.

Sims, P.K., 1980, Boundary between Archean greenstone and gneiss terranes in northern Wisconsin and Michigan, *in* Morey, G.B., and Hanson, G.N., eds., Selected Studies of Archean Gneisses and Lower Proterozoic Rocks, Southern Canadian Shield: Geological Society of America Special Paper 182, p. 113-124.

Sims, P.K., 1991, Great Lakes tectonic zone in Marquette Area, Michigan-Implications for Archean tectonics in north-central United States: U.S. Geological Survey Bulletin 1904-E, p. E1-E17.

Sims, P.K., Schultz, K.J., Dewitt, E., and Brasaemle, B., 1993, Petrography and geochemistry of Early Proterozoic granitoid rocks in Wisconsin Magmatic Terranes of Penokean orogen, northern Wisconsin: U.S. Geological Survey Bulletin 1904-J, p. J1-J31.

VanWyck, N. and Norman, M., 2004, Detrital Zircon Ages from Early Proterozoic Quartzites, Wisconsin, Support Rapid Weathering and Deposition of Mature Quartz Arenites: The Journal of Geology, v. 112, p. 305-315.

VanWyck, N. and Johnson, C.M., 1997, Common lead, Sm-Nd, and U-Pb constraints on petrogenesis, crustal architecture, and tectonic setting of the Penokean orogeny (Paleoproterozoic) in Wisconsin: Geological Society of America Bulletin, v. 109, no. 7, p. 799-808.