Andrew J. Smye

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Research Interests

Field, experimental and theoretical investigation of metamorphic processes and their tectonic implications in the deep crust and subduction zones.

Academic Appointments

July 2022 – present	**Associate Professor of Geoscience**
April 2016 – July 2022	**Assistant Professor of Geoscience** Department of Geosciences, The Pennsylvania State University
March 2015 – April 2016	**NERC Independent Research Fellow** Department of Earth Sciences, University of Oxford
Sept. 2012 – March 2015	**Jackson Distinguished Postdoctoral Fellow** Department of Geological Sciences, Jackson School of Geosciences University of Texas at Austin
August 2011 – Sept. 2012	**Post-Doctoral Research Associate** NERC Isotope Geoscience Laboratories, British Geological Survey

Educational Background

February 2012	**Ph.D.**, "*The Tectonometamorphic Evolution of the Eclogite Zone, Tauern Window, Eastern Alps*" University of Cambridge Supervisors: Tim Holland, Mike Bickle; Committee: Chris Hawkesworth, Marian Holness
June 2007	**M.Sci.**, Earth Sciences (*First-class honors*) University of Oxford Research advisors: Dave Waters and Marc St-Onge (Geological Survey of Canada)

Awards and Honors

2021 **NSF CAREER**
2018 **Faculty Position**, University of Oxford (*declined*)
2017 **Rudy L Slingerland Early Career Assistant Professorship**, Penn State
2017 **President's Award, Geological Society of London**
2015 **Junior Research Fellowship** (*non-stipendiary*), St Edmund Hall, Oxford
2014 **NERC Independent Research Fellowship**
2012 **Jackson School Distinguished Postdoctoral Fellowship**
2010 **BP Scholarship**
2010 **Tony Carswell Award**, Metamorphic Studies Group
2009 **Magdalene College Travel Award**
2007 **St Edmund Hall Academic Scholarship, University of Oxford**
2006 **Keith Cox Prize**, University of Oxford
2006 **Geological Survey of Canada Research Placement**

2005 **Geological Survey of Canada Research Placement**
2005 **St Edmund Hall Travel Award**
2007 **St Edmund Hall Academic Exhibition**

Funding Obtained

2022	**NSF A Geochemical Approach to Quantifying the Magnitude of Strain and Fluid Flow along the Subduction Interface** (Co-PI, EAR-2214324, $518,605)
2021	**NSF Determining the rates and conditions of subduction initiation beneath the Samail Ophiolite** (Co-I, EAR-2120931, $199,802)
2021	**NSF CAREER: Developing noble gases as tracers of metamorphic dehydration** (PI, EAR-2047024, $635,630)
2020	**NSF How Are Ultrahigh Temperatures Attained in Continental Crust?** (PI, EAR-2025122, $279,812)
2019	**NSF How Does Lower Continental Crust Form?** (PI, EAR-1927631, $233,562)
2016	**Penn State Gladys Snyder Award** $5,000 in support of teaching petrology
2016 – 2021	**NSF-PIRE: ExTerra Field Institute and Research Endeavor** (Senior personnel, EAR-1545903, $4,022,940 split between 9 institutions)
2015 – 2020 (*terminated 2016*)	**NERC Independent Research Fellowship** Noble gas systematics of subduction, University of Oxford, U.K.: £514,272
2012 – 2015	**Jackson Postdoctoral Fellowship** University of Texas, U.S.A.: $140,000
2009	**NERC Facilities grant** IP/1068/1108 (Co-I, £21,100), U-Pb geochronology

Invited Seminars

2020 Goethe-Universität Frankfurt, Germany
2020 Penn State, Geodynamics colloquium, PA
2020 Goldschmidt Virtual Conference. Applications and Limitations of U-Pb Thermochronology (*Keynote*)
2019 Tulane, New Orleans
2019 Virginia Tech, VA
2019 Simon Fraser University, Canada
2019 Penn State Chill & Spill PA
2018 Princeton, NJ
2018 University of Oxford, UK
2018 EGU General Assembly, Vienna. Session: Trace elements and isotopes: the markers of geological change.
2018 Penn State Geocheminar, PA
2018 Penn State Geology Club, PA
2018 Columbia University, NY
2018 Syracuse University, NY
2017 AGU Fall Meeting, New Orleans. Session: Evolution and Architecture of Rifts.
2017 AGU Fall Meeting, New Orleans. Session: Petrochronology and Microstructural Geochronology.
2017 Goldschmidt conference, Paris. Session: Innovations in Thermochronology.
2017 Carnegie Institute, Washington D.C.
2017 Johns Hopkins, Baltimore
2017 GeoPRISMS Rifting Initiation & Evolution Workshop, Albuquerque, New Mexico
2016 GeoPRISMS Subduction Zone Observatory (*pop-up talk*)
2016 University of Rochester, NY

2016 Baylor University, TX
2016 Penn State Geocheminar, PA
2016 Michigan State University, MI
2016 Yale University, CT
2016 University of Cambridge, UK
2015 AGU Fall Meeting. Session: Resolving Process through Geochronology
2015 University of St Andrew's, UK
2015 Goldschmidt Geochemistry Conference, Prague, CZ. Session: Accessory Mineral Petrology, Geochemistry, Geochronology, Diffusion, and Kinetics. (*Keynote*)
2015 University of Oxford, UK
2014 Jackson School of Geosciences, Austin, TX
2014 Goldschmidt Geochemistry Conference, Sacramento, CA. Session: Putting the little t in P-T-H2O-t: Novel integrations of geochronology and thermodynamics in diverse tectonic regimes
2014 Goldschmidt Geochemistry Conference, Sacramento, CA. Session: Geologic and geochemical processes at the plate interface
2014 The Pennsylvania State University, State College, PA

Workshops and Courses

2019 **E-FIRE Eastern Alps Workshop, Switzerland/Italy**
2019 **GeoPRISMS Synthesis Workshop, San Antonio, TX**
2018 **E-FIRE Synthesis Workshop, Boston College**
2017 **E-FIRE Alps Workshop, Italy**
2017 **GeoPRISMS Rifting Initiation and Evolution Workshop, Albuquerque, New Mexico**
2017 **ICDP Drilling the Lower Crust Workshop, Verbano, Italy**
2016 **E-FIRE pre-AGU Workshop, San Francisco, CA**
2016 **Subduction Zone Observatory, Boise, ID**
2016 **Early Career Geoscience Faculty Workshop, U. Maryland, MD**
2013 **International Lithosphere Program**
Nature of the Plate Interface in Subduction Zones Workshop, California
2012 **NERC Grantsmanship short course**
British Geological Survey, Keyworth (2 days)
2012 **Nuts and Bolts of sector-field isotope ratio mass spectrometry**
Geochemical Society funded; University of Bristol (3 days).
2011 **GTSnext ^{40}Ar–^{39}Ar and U–Pb geochronology workshop**
Marie Curie FP7; NIGL, U.K. (2 days)
2010 **GTSnext radiogenic isotopic geochronology workshop**
Marie Curie FP7; Verbania, Italy (5 days)
2009 **EURISPET HP metamorphism and subduction zones workshop**
Places competitively awarded; Marie Curie FP6; Granada, Spain

Mentoring Experience

Post-doctoral Research Fellows

2019 – 2021	Joshua Garber, Ph.D. University of California, Santa Barbara *Now Assistant Research Professor, Penn State*
2016 – 2018	Spencer Seman, Ph.D. University of Texas, Austin *Now senior research scientist, McCrone Group, Chicago*

Current Graduate Student Advisees

2021 –	Leonie Ströbl, Ph.D. candidate *Developing noble gases as tracers of metamorphic dehydration*
2019 –	Charlotte Connop, Ph.D. candidate *Crustal differentiation in the Pyrenees*

Graduated students

2018 – 2022	Jacob Cipar, Ph.D. *Thermal evolution of the Rio Grande Rift and Basin and Range lithosphere: a petrochronologic investigation*
2019 – 2021	Hailey Mundell, MS *Fluid-flow under sub-arc conditions: a petrological investigation of eclogite-facies veins, Eclogite Zone, Eastern Alps*
2017 – 2019	Marit Wyatt, MS *How are sediments incorporated into lower crust? A petrochronological investigation of the Ivrea Zone*

Committee memberships

2020 –	Eirini Poulaki, Ph.D., UT Austin, "Tectonic evolution of the Betic-Rif orogen" (*advisor: Daniel Stockli*)
2020 –	Raphael Affinito, Ph.D., Penn State, "Earthquake nucleation, triggering and relationships with aseismic processes" (*advisor: Chris Marone*)
2020 –	Cristy Stoain, MS, Penn State, "Constraints on crustal growth from zircon Hf systematics, Slave Craton" (*advisor: Jesse Reimink*)
2020 – 2022	Alex Thames, Ph.D., Penn State, "Modelling the mantle water cycle" (*advisor: Brad Foley*)
2019 – 2021	Copeland Cromwell, MS, Penn State, "Using Animations of Earthquake Sequences to Get Insight into Earthquake Processes" (*advisor: Kevin Furlong*)
2019 –	Hee Choi, Ph.D., Penn State, "Geodynamic implications of continental crust for subduction initiation on early Earth." (*advisor: Brad Foley*)
2018 –	Tsai-Wei Chen, Ph.D., Penn State, "The role of silica kinetics on plate interface rheology" (*advisor: Don Fisher*)
2018 – 2020	Sofia Johnson, MS, Penn State, "Magmatism and metasomatism, Katwe-Kikorongo volcanic field" (*advisor: Tanya Furman*)
2018 – 2019	Shelby Bowden, Ph.D., Penn State, "Petrogenesis of Saudi Arabian Basalts" (*advisor: Tanya Furman*)
2018 – 2020	Collin Oborn, MS, Penn State, "Geochemical insights into post-glacial volcanism in Iceland's Eastern Volcanic Zone: the Tungnarhraun lava flows" (*advisor: Tanya Furman*)
2017 – 2019	Gabbrielle Ramirez, MS, Penn State (*advisor: Don Fisher*)
2017 – 2019	Matt Reinhold, MS, Penn State, "Constraints on Earth's Thermal Evolution from the Heavy Noble Gas Content of the Mantle" (*advisor: Brad Foley*)
2021 –	Daniel Guarin, Ph.D., Penn State, "Predisposition of Geomorphic Processes to Forest Composition" (*external unit member; advisor: Patrick Druhan*)

Undergraduate Research Students Advised

Aug 2021 – Aug 2022	Gabby Mentgen *Trace element zonation of ultra-high temperature garnet, Kilborne Hole*
Aug 2019 – May 2020	Morgan Richards *Fabric analysis of metapelitic xenoliths, Kilborne Hole*
Aug 2018 – May 2019	Megan Debreau *A Detrital Zircon Investigation of the Ivrea Zone*
Aug 2018 – May 2019	Yihua Lui *Titanite Geochemistry and Geochronology in the Western Alps*
Aug 2018 – May 2019	Martina Dundovic *Feldspar Thermometry of Lower Crustal Metapelites, Rio Grande Rift*
Aug 2018 – May 2019	Hannah Pattel *P-T Conditions of Lower Crustal Metapelities, Rio Grande Rift*
Aug 2017 – May 2018	Ian Wolfe *Combined Ti-in-quartz and microstructural study of the Alta aureole*
June – Nov 2017	Jacob Cipar *Al-Cr diffusion in spinel: constraints on mantle exhumation rates*
May 2016 – Sept 2016	Mike Hudak *Al diffusion in orthopyroxene*

Courses Taught

Earth Materials (GEOSC 201)	undergrad majors (n=30-60)	Spring 2017, 2018, 2019, 2020, 2021, 2022
Principles of Igneous and Metamorphic Petrology (GEOSC 460)	undergrads, grads (8-15)	Fall 2017, 2018, 2019, 2021
Field Camp (GEOSC 472A)	undergrads (20-50)	Summer 2017,2018,2019,2020,2021
Crustal Evolution Seminar (GEOSC 497)	graduates (10)	Fall 2018
Advanced Isotope Geochemistry (GEOSC 597)	undergrads,grads (12)	Spring 2017
Computational Petrology (GEOSC 597)	grads (8)	Spring 2020
Isotope Geochemistry of the Solid Earth (GEOSC 518e)	grads (3)	Spring 2022

Service

Penn State

August 2020 –	EPMA Working Group (*Chair*)
September 2020 –	EMS 125th Anniversary Celebration Committee
August 2020 –	Executive Committee
August 2020 –	Undergraduate Program Committee
June 2020 –	Colloquium Committee
March 2021 – April 2021	Erickson Discovery Grants Committee
March 2020 – April 2020	Erickson Discovery Grants Committee
August 2018 - August 2019	Basement Renovation Committee
October 2018 - February 2019	Admissions Committee
August 2017 - August 2018	Executive Committee, Member
August 2017 - August 2018	Graduate Program Committee
August 2017 - December 2017	Faculty Search in Solid Earth Geochemistry
November 2016 - March 2017	Faculty Search in Sedimentary Geology
October 2016 - March 2017	Graduate Admissions Committee

National and international communities

2022 –	Associate Editor for the *American Journal of Science*
2022	Panelist, NSF Geochemistry and Petrology program
2021	Thermo 2021, Session Co-convener: "Additional Noble Gas and Solid State Thermochronometers"
2021	Panelist, NSF-Post-doc Fellowship Scheme
2020	PI, GeoPRISMS workshop proposal: "Feedbacks Between Deformation and Metamorphism in the Lithosphere" (*declined by NSF*)
2019	AGU Topical Session Co-convener: Frontiers of Subduction Zone and Regional Metamorphism: Fluids, Reactions, and Dynamics
2019	AGU Topical Session Co-convener: Rates and Timescales of Magmatic and Dynamic Processes: Insights from Thermobarometry and Geospeedometry
2019	Discussion Facilitator GeoPRISMS synthesis meeting, San Francisco
2019	Discussion Facilitator GeoPRISMS synthesis meeting, New Orleans
2017	Goldschmidt Session Co-convener: "Tectonochemistry"
2017	Petrology co-ordinator on ICDP DiVE (Drilling the Ivrea-Verbano Zone) proposal, submitted Jan 2018
2017	GSA Topical Session Co-convener: Metamorphic Records of Heat and Mass Transfer
2016 –	Reviewer for: NSF-Tectonics, NSF-Petrology, NSF-Instrumentation and Facilities, NSF-FRES, NSF-Post-doc Fellowship Scheme, European Research Council, NSERC (Canada), NERC (UK) (*3-4 reviews per year*)
2015 –	Reviewer for: American Journal of Science, EPSL, Geology, Journal of Metamorphic Geology, G3, Lithos, Terra Nova, JAES, Contributions to Mineralogy and Petrology, Tectonics, Nature, RiMG, Journal of Geological Society, Precambrian Geology, Science Advances, Journal of Geophysical Research: Solid Earth (*8-10 reviews each year*)

Professional Affiliations

American Geophysical Union
Geochemical Society
Metamorphic Studies Group

List of Publications

*denotes undergraduate, **graduate student and ***post-doc in research group
h index: 16; total citations: 765 (*Google Scholar*)

Submitted

Cipar,* J., **Smye, A.**, Garber, J., Reimink, J. and Kylander-Clark, A.R.C.. Attenuation of Laramide continental lower crust and mantle lithosphere: a zircon depth-profile petrochronologic investigation, *submitted to Tectonics*

England, P.C. and **Smye, A.J.** Metamorphism and Deformation on Subduction Interfaces I: Thermal and Mechanical Framework; *submitted to* G^3

Smye, A.J. and England, P.C. Metamorphism and Deformation on Subduction Interfaces II: Petrological and Tectonic Implications; *submitted to* G^3

Published or in press

32. Lamont, T., **Smye, A.**, Roberts, N., Searle, M., Waters, D. and White, R. Constraints on the thermal evolution of metamorphic core complexes from the timing of high- pressure metamorphism on Naxos, Greece, *GSA Bulletin, vol. 34, doi.org/10.1130/B36332.1*
31. Guevara, V., **Smye, A.J.**, Caddick, M., Searle, M., Olsen, T., Whalen, L., Kylander-Clark, A.R.C., Jercinovic, M. and Waters, D.. A modern pulse of plate-velocity exhumation and diachronous crustal melting in the Nanga Parbat Massif; *Science Advances, volume 8, issue 31; DOI: 10.1126/sciadv.abm2689*
30. Wyatt, D.**, **Smye, A.J.**, Garber, J.*** and Hacker, B. Assembly and tectonic evolution of continental lower crust: Monazite petrochronology of the Ivrea-Verbano Zone (Val Strona di Omegna); *Tectonics, 41(3), e2021TC006841*
29. Garber, J., Rioux, M., Searle, M., Kylander-Clark, A., Hacker, B., Vervoort, J., Warren, C., and **Smye., A.J.** Dating continental subduction beneath the Samail Ophiolite: garnet, zircon, and rutile petrochronology of the As Sifah eclogites, NE Oman, *Journal of Geophysical Research-Solid Earth, 126(12), e2021JB022715*
28. Ramirez, G.**, **Smye, A.J.**, Fisher, D., Hashimoto, Y., and Yamaguchi, A. Constraints on element mobility during deformation within the seismogenic zone, Shimanto Belt, Japan; *Geochemistry, Geophysics, Geosystems, 22(8), e2020GC009594*
27. Fisher, D., Hooker, J., **Smye, A.J.**, and Chen, T-W. Insights from the Geological Record of Deformation along the Subduction Interface at Depths of Seismogenesis, accepted, *Geosphere, 17 (6): 1686–1703*
26. **Smye, A.**, Seman, S.M.***, Scambelluri, M., Starr, P. and Federico, L., 2021. Exhumation dynamics of high-pressure metamorphic rocks from the Voltri Unit, Western Alps: constraints from phengite Rb-Sr geochronology, *Contributions to Mineralogy and Petrology*, 176:14
25. Cipar, J.**, Garber, J.***, Kylander-Clark, A. and **Smye, A.**, 2020. Active differentiation of continental crust beneath the Rio Grande Rift, *Nature Geoscience*, 13, 758–763
24. Paul Starr, Kirkland S Broadwell, Besim Dragovic, Marco Scambelluri, Anne A Haws, Mark J Caddick, Andrew J Smye, Ethan F Baxter. 2020. The Subduction and Exhumation History of the Voltri Ophiolite, Italy: evaluating exhumation mechanisms for High-Pressure Metamorphic Massifs, *Lithos*, 376, 105767
23. Garber, J.***, **Smye, A.J.**, Feineman, M., Kylander-Clark, A. and Matthews, S. Decoupling of zircon U-Pb and trace-element systematics driven by reaction-induced U diffusion in eclogite-facies zircon (Monviso meta-ophiolite, W. Alps), in press, *Contributions to Mineralogy and Petrology*, 2020.
22. Nick M W Roberts, Matthew S A Horstwood, Daniel J Condon, Kerstin Drost, David Chew, Henrik Drake, Antoni E Milodowski, Noah M McLean, **Smye, A.J.**, Richard J Walker, Richard Haslam, Keith

Hodson, Jonathan Imber, and Nicolas Beaudoin. 2020. LA-ICP-MS U-Pb carbonate geochronology: strategies, progress, and application to fracture-fill calcite, in press, *GChron*, 2020.

21 **Smye**, **A**.**J**., Lavier, L., Zack, T. and Stockli, D. Episodic heating of continental lower crust: a thermal modeling investigation of the Ivrea Zone; *Earth and Planetary Science Letters*, 2019–521, 158-168.

20 Fisher, D., **Smye**, **A**.**J**., Marone, C., van Keken, P. and Yamaguchi, A. Kinetic Models for Healing of the Subduction Interface based on Observations of Ancient Accretionary Complexes; *Geochemistry, Geophysics, Geosystems*, 2019.

19 Lamont, T., Searle, M.P., Waters, D.J., Roberts, N.M.W., Palin, R., **Smye**, **A**.**J**., Dyck, B., Weller, O. and St-Onge, M. Compressional origin of the Naxos metamorphic core complex, Greece: Structure, petrography, and thermobarometry; *Geological Society of America Bulletin*, 2019.

18 **Smye**, **A**.**J**., Marsh, J., Vermeesch, P., Garber, J. and Stockli, D. Applications and Limitations of U-Pb Thermochronology to Middle and Lower Crustal Thermal Histories; *invited review article for Chemical Geology*, 2018–494: 1-18.

17 McKenzie, R, **Smye**, **A**.**J**., Hegde, G.V. and Stockli, D.F., Continental growth histories revealed by detrital zircon trace elements: A case study from India; *Geology*, 2018–46 (3): 275-278.

16 Foley, B. and **Smye**, **A**.**J**., Carbon cycling and habitability of stagnant lid planets; *accepted, Astrobiology*, 2018.

15 Wade, J., Dyck, B., Palin, R., Moore, J. and **Smye**, **A**.**J**., Divergent fates of primitive water on Earth and Mars; *Nature*, 2017–552, 391–394.

14 Marsh, J., and **Smye**, **A**.**J**.. U-Pb systematics and trace element characteristics in titanite from a HP mafic granulite; *Chemical Geology*, 2017–466, 403–416.

13 **Smye**, **A**.**J**., Seman, S.***, Hudak, M.* and Crispin, K.. Rates of mantle cooling and exhumation during rifting constrained by REE-in-orthopyroxene speedometry; *Geochemistry, Geophysics, Geosystems*, 2017–18, 2510–2525.

12 **Smye**, **A**.**J**., Jackson, C.R.M., Konrad-Schmolke, M., Hesse, M.A., Parman, S.W., Shuster, D.L. and Ballentine, C.J. Noble gases recycled into the mantle through cold subduction zones; *Earth and Planetary Science Letters*, 2017–471, 65–73.

11 Seymour, N., Stockli, D., Beltrando, M. and **Smye**, **A**.**J**. Tracing the thermal evolution of lower continental crust through continental extension; *Tectonics*, 2016–35; doi: 10.1002/2016TC004178.

10 Bracciali, L., Parrish, R., Najman, Y., Carter, A., Wijbrans, J. and **Smye**, **A**.**J**. Plio-Pleistocene exhumation of the eastern Himalayan syntaxis and its domal 'pop-up'; *Earth Science Reviews*, 2016–160, 350–385.

9 Sathaye, K., **Smye**, **A**.**J**., Jordan, J. and Hesse, M. Noble gases preserve history of retentive continental crust; *Earth and Planetary Science Letters*, 2016–443, 32–40; doi: 10.1016/j.epsl.2016.03.014.

8 Jackson, C.R.M., Shuster, D., Parman, S.W. and **Smye**, **A**.**J**. Noble gas diffusivity hindered by low energy sites in amphibole; *Geochimica et Cosmochimica Acta*, 2015; doi:10.1016/j.gca.2015.09.024.

7 **Smye**, **A**.**J**. and Stockli, D. Rutile U-Pb age depth profiling: a continuous record of lithospheric thermal evolution; *Earth and Planetary Science Letters*, 2014–408, 171–182; doi: 10.1016/j.epsl.2014.10.013.

6 **Smye**, **A**.**J**., Roberts, N., Condon, D.J., Horstwood, M.S.A., Parrish, R.R. and Noble, S.R. Characterizing the U-Th-Pb systematics of allanite by ID and LA-ICPMS: implications for geochronology; *Geochimica et Cosmochimica Acta*, 2014–135, 1–28; doi:10.1016/j.gca.2014.03.021.

5 **Smye**, **A**.**J**., Warren, C. and Bickle, M.J. The signature of devolatisation: extraneous ^{40}Ar systematics in high-pressure metamorphic rocks; *Geochimica et Cosmochimica Acta*, 2013–113, 94–112; doi:10.1016/j.gca.2013.03.018.

4 Warren, C., **Smye**, **A**.**J**., Kelley, S. and Sherlock, S. Using white mica ^{40}Ar/^{39}Ar data as a tracer for fluid flow and permeability under high-P conditions: Tauern Window, Eastern Alps; *Journal of Metamorphic Geology*, 2011–30, 63–80; doi:10.1111/j.1525-1314.2011.00956.x.

3 **Smye**, **A**.**J**., Bickle, M.J., Holland, T.J.B., Parrish, R.R. and Condon, D.J. 2011. Rapid formation and exhumation of the youngest Alpine eclogites: A thermal conundrum to Barrovian metamorphism;

Earth and Planetary Science Letters, 2011–306, 193–204; doi:10.1016/j.epsl.2011.03.037.

2 **Smye**, **A**.**J**., Greenwood, L., and Holland, T.J.B., 2010. Garnet–chloritoid–kyanite assemblages: Eclogite facies indicators of subduction constraints in orogenic belts; *Journal of Metamorphic Geology*, 2010–28, 753-768; doi: 10.1111/j.1525-1314.2010.00889.x.

1 **Smye**, **A**.**J**., St-Onge, M.R., and Waters, D.J., 2009. Contrasting metamorphic pressure–temperature histories within the Trans-Hudson Orogen's hinterland, southwest Baffin Island, Nunavut; *Geological Survey of Canada, Current Research* 2009–6, 18 p.