The Rock Record – March 2007

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In This Issue

Monday March 12th

Secular tectonic evolution of Archean continental crust: interplay between horizontal and vertical processes in the formation of the Pilbara Craton, Australia

Dr. Martin Van Kranendonk
Western Australia Geological Survey

Co-Sponsored with U of R Geology Department

Coffee and Donuts: 5:00 pm
Talk: 5:15 pm

College West room 115, University of Regina

Tuesday March 13th

Volcanic degassing, hydrothermal circulation and the flourishing of early life on Earth: new evidence from the Warrawoona Group, Pilbara Craton, Western Australia

Dr. Martin Van Kranendonk
Western Australia Geological Survey

Co-Sponsored with U of R Geology Department

Lancaster Room, Royal Canadian Legion
Cash Bar: 11:30; Lunch: 11:50
Talk: 12:15 – 13:00
Members $7.00, Non-members $11.00
Contact: Nadene Hagen 790-4160
By NOON, Monday, March 12th

Thursday March 15th

Ancient Pancontinental River Systems Revealed by Detrital Zircon Geochronology of Proterozoic Cratonic Sheet Sandstones

GAC Howard Street Robinson Lecturer
Dr. Rob Rainbird
Geological Survey of Canada

Co-Sponsored with U of R Geology Department

Coffee and Donuts: 5:00 pm
Talk: 5:15 pm

College West room 115, University of Regina

Wednesday March 21st

Intrusion Deformation and Degassing at the Yellowstone Caldera

AAPG Distinguished Lecturer
Dr. Jacob B. Lowenstern
US Geological Survey Menlo Park, California

Lancaster Room, Royal Canadian Legion
Cash Bar: 11:30; Lunch: 11:50
Talk: 12:15 – 13:00
Members $7.00, Non-members $11.00
Contact: Nadene Hagen 790-4160
By NOON, Monday, March 12th

LUNCHEON TALKS:

MARCH 12TH, 2007

Secular tectonic evolution of Archean continental crust: interplay between horizontal and vertical processes in the formation of the Pilbara Craton, Australia

Martin J. Van Kranendonk1, R. Hugh Smithies1, Arthur H. Hickman1, and David C. Champion2
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ABSTRACT
The Archean Pilbara Craton contains five geologically distinct terranes — the East Pilbara, Karratha, Sholl, Regal, and Kurrana Terranes — all of which are unconformably overlain by the 3.02-2.93 Ga De Grey Superbasin. The 3.53-3.17 Ga East Pilbara Terrane represents the ancient nucleus of the craton that formed through three distinct mantle plume events at 3.53-3.43 Ga, 3.35–3.29 Ga, and 3.27–3.24 Ga. Each plume event resulted in eruption of thick, dominantly basaltic volcanic successions on older crust to 3.72 Ga, and melting of crust to generate first TTG, and then progressively more evolved granitic magmas. In each case, plume magmatism was accompanied by uplift and crustal extension. The combination of conductive heating from below, thermal blanketing from above, and internal heating of buried granitoids during these events led to episodes of partial convective overturn of upper and middle crust. These mantle melting events caused severe depletion of the subcontinental lithospheric mantle, making the EP a stable, buoyant, unsubductable continent by c. 3.2 Ga. Extension accompanying the latest event led to rifting of the protocontinent margins at between 3.2-3.17 Ga.

After 3.2 Ga, horizontal tectonic forces dominated over vertical forces, as revealed by the geology of the three terranes (Karratha, Sholl, and Regal) of the West Pilbara Superterrane. The c. 3.12 Ga Whundo Group of the Sholl Terrane is a fault bounded, 10 km–thick volcanic succession with geochemical characteristics of modern oceanic arcs (including boninites and evidence for flux melting) that indicate steep Archean subduction. At 3.07 Ga, the 3.12 Ga Sholl Terrane, 3.27 Ga Karratha Terrane and c. 3.2 Ga Regal Terrane accreted together and onto the East Pilbara Terrane during the Prinsep Orogeny. This was followed by development of the De Grey Superbasin - an intracontinental sag basin, and widespread plutonism (2.99-2.93 Ga) as a result of orogenic relaxation and slab breakoff. Craton-wide compressional deformation at 2.95-2.93 Ga culminated with 2.91 Ga accretion of the 3.18 Ga Kurrana Terrane with the East Pilbara Terrane. This compression caused amplification of the dome-and-keel structure in the East Pilbara Terrane. Final cratonization was effected by emplacement of 2.89-2.83 Ga post-tectonic granites.

Volcanic degassing, hydrothermal circulation and the flourishing of early life on Earth: new evidence from the Warrawoona Group, Pilbara Craton, Western Australia.

Martin J. Van Kranendonk

Abstract
New data gathered during mapping of c. 3490-3240 Ma rocks of the Pilbara Supergroup in the Pilbara Craton show that most bedded chert units originated as epiclastic and evaporative sedimentary rocks that were silicified by repeated pulses of hydrothermal fluids that circulated through the footwall basalts during hiatuses in volcanism. For most cherts, fossil hydrothermal fluid pathways are preserved as silica ± barite ± Fe-bearing veins that cut through the footwall and up to the level of individual bedded chert units, but not above, indicating the contemporaneity of hydrothermal silica veining and bedded chert deposition at the end of volcanic eruptive events. Silica ± barite ± Fe-bearing vein swarms are accompanied by extensive hydrothermal alteration of the footwall to the

bedded chert units, and occurred under alternating high-sulphidation and low-sulphidation conditions. These veins provided pathways to the surface for elements leached from the footwall (e.g. Si, Ba, Fe) and volcanogenic emissions from underlying felsic magma chambers (e.g. CO_2, H_2S/HS^-, SO_2).

Stratigraphic evidence of shallowing upward and subsequent deepening associated with the deposition of Warrawoona Group cherts is interpreted to relate to the emplacement of subvolcanic laccoliths and subsequent eruption and/or degassing of these magmas. Heat from these intrusions drove episodes of hydrothermal circulation. Listric normal faulting during caldera collapse produced basins with restricted circulation of seawater. Eruption of volcanogenic emissions into these restricted basins formed brine pools with concentration of the volcanogenic components, thereby providing habitats suitable for early life forms.

Fossil stromatolites from two distinct stratigraphic units in the North Pole Dome grew in shallow water conditions, but in two very different geological settings with different morphologies. Stratiform and domical stromatolites in the stratigraphically lower, c. 3490 Ma Dresser Formation of the Warrawoona Group are intimately associated with barite and chert precipitates from hydrothermal vents, suggesting that component microbes may have been chemoautotrophic hyperthermophiles. Evidence of shallow water to periodically exposed conditions, active growth faulting and soft sediment deformation indicates that the volcanogenic emissions were erupted into a shallow water, tectonically active caldera and concentrated therein to produce an extreme habitat for early life. Widespread conical and pseudocolumnar stromatolites in the c. 3400 Ma, Strelley Pool Chert at the base of the unconformably overlying Kelly Group, occur in shallow marine platform carbonates. Silicification was the result of later hydrothermal circulation driven by heat from the overlying, newly erupted Euro Basalt. The markedly different morphology and geological setting of these only slightly younger stromatolites compared with the Dresser Formation suggests a diversity of microbial life on early Earth.

The biogenicity of putative microfossils from this and younger hydrothermal silica veins in the Warrawoona Group remains controversial and requires further detailed study.

Martin Van Kranendonk is a senior geologist with the Geological Survey of Western Australia, where he has been employed since 1997. Trained in Canada (BSc: Toronto, 1984; MSC: Toronto, 1987; PhD: Queens University, 1992), Martin moved to Australia in 1994 to study the origin of the dome-and-keel architecture of the Archean Pilbara Craton as a post-doctoral fellow at the University of Newcastle, and has been mapping in the Pilbara ever since. His main interests are Archean tectonics and the geological setting of early life on Earth, and he is widely published in these fields. Martin is an associate editor of Precambrian Research, the senior editor of an upcoming Elsevier book on Earth's Oldest Rocks, an associate member of the Australian Centre for Astrobiology, and Vice-Chair of the Precambrian Subcommission of the International Commission on Stratigraphy. He has appeared on numerous television and radio documentaries on early Earth, and has been involved in educational outreach programs for school children and the general public.

Ancient Pancontinental River Systems Revealed by Detrital Zircon Geochronology of Proterozoic Cratonic Sheet Sandstones

Robert H. RAINBIRD, Geological Survey of Canada (GSC), 615 Booth St., Ottawa, Ontario, Canada K1A 0E9; rrainbir@nrcan.gc.ca

Prior to 400 Ma, the lack of substantial vegetative cover accompanied by a rigorous chemical and physical weathering regime promoted deposition of thick, quartzose, cratonic sheet sandstones, examples of which are preserved in several intercontinental Proterozoic basins in Canada. The tectonic setting and provenance of these extensive deposits have been investigated by U-Pb dating of detrital zircon using a variety of analytical techniques over the past 15 years. This research was initially applied to assess the provenance of fluvial sandstones of the early Neoproterozoic Shaler Supergroup in the Canadian Arctic. These and other correlative sandstones exhibit consistent northwesterly paleocurrents suggesting that they were derived from erosion of the adjacent craton. Detrital zircon geochronology supported this assertion but the majority of the detrital zircons yielded late Mesoproterozoic ages, unlike the age of any known proximal source terrain, but quite similar to the age of extensive synorogenic plutons in the Grenville province of southeastern Laurentia. This observation led to the development of a hypothesis whereby detritus was transported approximately 3000 km northwestward from the rising Grenvillian orogeny by a fluvial system of pan-continental proportions. The "big-river hypothesis" was tested by comparing the detrital zircon geochronology of the Shaler Supergroup with that of potentially correlative strata from the northern Canadian and southern U.S. Cordillera. The results strongly supported the hypothesis and suggested that the fluvial system was laterally extensive and may have formed a broad cratonic sheet originating from multiple sources along the great length of the Grenvillian mountain front. Proximal parts of the big-river system may be present in a westward-tapering wedge of coarse, immature clastic red-beds of interpreted Neoproterozoic age from the subsurface of western Ohio. Detrital zircons from these strata are overwhelmingly of Mesoproterozoic age with the bulk falling in the 1.2-1.0 Ga age span characteristic of the main collisional phase of the Grenvillian orogeny. These rocks were interpreted as the molassic phase of a previously unrecognized foreland basin to the Grenville orogen. Remnants of the river system are now recognized in Neoproterozoic basins on several other continental blocks (e.g. Australia, Siberia and Baltica) that were rifted apart with the break-up of the supercontinent Rodinia and these have been used to help constrain its reconstruction. Other examples of large-scale fluvial sheet sandstones are preserved in the late Paleoproterozoic Athabasca, Thelon and Amundsen basins and this is supported by recent provenance analyses employing detrital zircon geochronology.

Intrusion, Deformation and Degassing at the Yellowstone Caldera

Dr. Jacob B. Lowenstern

The Yellowstone caldera is well known for its cycles of uplift and subsidence over both historic and geologic timescales. Most models for deformation assume sources due to transport of magma or hydrothermal brine streaming through ruptured permeability barriers. Recent investigations of chemical mass balance at Yellowstone provide critical insights into potential sources of both deformation and heat. Volatile fluxes from the Yellowstone caldera have been calculated by summing the flux of Cl–, F, SO42–, and HCO3– through the major rivers leaving the Yellowstone Plateau. Long-term studies show that Cl–, the primary non-H2O component of geothermal brines has not changed appreciably in output during recent periods of subsidence and uplift. Instead, Cl– flux is dominated by recharge constraints, increasing during periods of greater precipitation. Carbon is much more abundant than sulfur in Yellowstone's waters, but is even more

dominant when combined with data on gas flux from fumaroles and diffuse degassing. In fact, CO2 is about 300 times more abundant than Cl– on a molar basis as an effluent from the Yellowstone hydrothermal system. Similarly sulfur flux exceeds Cl– by about 25 times what one would expect from the concentrations in degassed volcanic rocks that could be leached. Phase equilibrium constraints imply that the shallow subsurface at Yellowstone (the upper two km) should be saturated with a CO2-rich vapor phase under most conceivable P-T conditions. This volumetrically significant (even dominant) phase should have an important role in pressurization of the hydrothermal system and may contribute to ongoing cycles of deformation within the caldera. The volatile "signature" from Yellowstone strongly suggests that gas discharge is controlled not by the crustal granitic magma chamber but by subjacent basaltic intrusions that provide both heat and mass to the overlying system.

Biography
Jacob B. Lowenstern, USGS Menlo Park, California
1992 Ph.D. –Stanford University, Stanford, California USA
1990 MS. –Stanford University, Stanford, California USA
1985 B.A. – Dartmouth College, Hanover, New Hampshire, USA
Experience:
2002- Scientist-in-Charge, Yellowstone Volcano Observatory
1994– Research Geologist, U.S. Geological Survey
1993-94 Postdoctoral Fellow, U.S. Geological Survey
1992-93 Research Associate, Geological Survey of Japan

OTHER EVENTS AND NOTICES:

Field trip planning meeting: March 22nd, 5:30pm at Cathedral Village Freehouse

There have been suggestions that the SGS might want to run a more ambitious field trip (e.g. Grand Canyon) in the future. This will be one topic of discussion at this meeting. There will also be preliminary planning for this summers field trip (probably to Stillwater Montana) and discussion about a one day spring field trip in southern Saskatchewan. Anyone interested in any of these topics is welcome to attend.

SGS Curling Bonspiel: Was held on Feb. 24th at Tartan Culring Club. It was a great success once again and a fun time was had by all.
Winners
1st event: John, Kate, Ken, Tyler
2nd event: Tony, Jeff, Sarah, Jen
3rd event: Pat, Neil, Kevin, Phillip
4th event: Lynn, Melanie, Sean, Dave

Photo Contest:

This is your last opportunity to submit entries for the SGS photo contest. We will be accepting entries until April 30th, 2007. Any photo with a Saskatchewan geology or landscape theme is eligible. We are considering turning the winning entries into a 2008 calendar. Please submit your photos through the SGS website.

SGS Merchandise For Sale

Looking for a distinctive gift? How about an SGS golf shirt or beer mug!

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